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# A Critical Study of Wireless Power Transfer in Electric Vehicles: A Review

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**Abstract:** The fields of magnetism and resonance are crucial to the operation of Electric Vehicle Wireless Communication (EVWC) devices. A magnetic field is produced when electricity flows through a coil of wire, just as it is in a transformer. For Wireless Power Transfer (WPT) to work, it's necessary to position two coils in such a way that one's magnetic field induces a current in the other. Unless the coils are very close to one another and aligned in a straight line, inductive power transfer is inefficient. In this paper work related to wireless charging system proposed by various researchers is explored. Concept of Static and dynamic charging, Inductive power transmission, wireless power transmission techniques including inductive and capacitive coupling, far field techniques like Radio, microwave and laser techniques are also presented.

**Index Terms-**WPT, Inductive and Capacitive power transfer technique, Far field techniques

## I. INTRODUCTION

An electrical source supplies energy to a transmitter, which in turn generates a time-varying electromagnetic field and distributes its power to an electrical load. Wireless power transfer technology makes electronic devices more portable, convenient, and secure by doing away with the need for batteries and wires. Wireless power transfer is a potential alternative if there is need to supply electricity to electronic equipment without physically connecting them with cords. The advantages of Wireless power Transfer (WPT) system is as follows.

- The charging procedure is straightforward and fully automated, requiring zero human intervention.
- Less space is needed for this setup compared to a traditional hardwired setup.
- It's more discrete and lightweight than a wired setup.
- Since there is no true connection, no live wires are on display.
- There is no longer any danger of electrocution when using corded devices.
- The most recent WPT designs are more efficient than their predecessors.

Everything is automated and intelligent in the twenty first century because it is programmed. WPT has numerous potential uses in today's environment, including supplying energy for mobile devices, medical implants, and electric vehicles [1,2]. For the inductive WPT charging process to work, the inductor must consist of a pair. The inductor's one end can function as the transformer's primary winding, while the other can serve in a similar capacity as the secondary winding. The function of the charger is to boost the AC power's voltage and frequency. When high-frequency AC is converted to DC on the charger's auxiliary side, the charging process is powered by the DC output of the charger. An efficient and successful charging infrastructure for electric vehicles requires a large air intake, a lot of force, and a high efficiency level [3]. Power in radio and microwave systems is transmitted via electromagnetic waves. Up to a certain distance, it is possible to distribute energy in this manner. There are a number of methods for recharging an electric vehicle's batteries, including magnetic resonance coupling, magnetic induction, microwave, and magnetic induction. In addition, a novel Inductive power transfer mechanism has been developed as a result of recent study. This low-natural-effect and secure solution [6] uses air gaps between the cushions (essential loops) set beneath the asphalt surface and the beneficiary cushion (auxiliary curl) installed beneath the vehicle's undercarriage to detach the vehicle from the electric force framework. In a 2kW building with a 125mm talk-about aperture, inductive coupling WPT technology can be activated in a number of ways [7]. To keep up with the rate at which battery limits are being approached, it is crucial to enhance the rate at which electric car batteries may be charged from a distance. Improved runtime can be achieved through tight coupling between the structure and the speed of motion [8-13].

## II. STEPS OF ALGORITHM TO WORK

Extensive study has been conducted by Cui et al. (2018) [14,15,16] for EV charging system. Battery swapping stations, charging stations, and wireless charging lanes are essential for electric vehicles due to their limited range. Their low adoption can be attributed to issues with standardization and the high expenses associated with developing them. Because charging stations may be configured to fit the demands of a wide range of network clients, they are becoming popular. The wide range of battery electric car sizes and types has not always been taken into account when planning the placement of charging stations. Charging stations of varying sizes and designs are required to meet the needs of network customers. In order to minimize the sum of all agents' travel times within a given capacitated network, we cast the model as a 0–1 mixed integer linear program (MILP).

According to Atmaja et al. (2015) [19,20], if a fixed charging station (FCS) is already in use at a certain location, the EV operator can bring a mobile charging station (MCS) and install a second pole. The MCS class of EVs includes vehicles with either a high charging station requirement or a limited energy storage capacity. There were two strains of MCS that spread: nES and wES. An MCS unit with many charging poles is nonetheless an MCS nES, even though it cannot store energy. This device can begin charging in on-grid mode [45] by connecting its input to the grid, reducing system strain. When used for EV charging outside of FCS, a device that combines MCS and energy storage is referred to as an MCS wES. Requesting a CS location is the first phase, followed by registering the EV once it arrives, starting the MCS, stopping the MCS, and finally finishing the charge. The CS server, EV, MCS, and FCS can all benefit from improved connectivity enabled by a web-based information management system. Even when the FCS is at full capacity, the waiting time for EVs is reduced using this strategy.

It is to note that the little temporal change in BEV incentives across our sample may explain why state income tax credits were not found to have a statistically significant influence on BEV adoptions by Clinton et al. (2019) [13]. The rebate offers for Teslas and other auto brands are as well received by consumers. We combine our results with earlier estimates of the marginal environmental costs associated with charging electric vehicles [15] to analyze the positive and negative externalities of BEV subsidy packages. Our research suggests that the benefits of these regulations may be exaggerated if the benefits of reduced emissions are ignored. The net utility may look very different depending on the relative importance of factors like market growth over the long term, production cost savings, network externalities, and quick innovation.

How long it takes to charge an electric vehicle was investigated by Yang et al. in 2013 [17,21,22]. Since EVs sometimes have to wait in line for a long time at a stationary CS, we propose a Mobile CS (MCS) management system to aid in charging pole mobility. The MCS service's operational data is stored in a Mobile Charging Information Management System. The simulation assesses how well the proposed system handles delays. Based on our findings, the MCS-based MC-IMS is superior to competing systems in its ability to fast charge EVs.

Atmaja et al. (2015) argue that stable funding for charging stations is crucial to launching a new age of ecologically responsible transportation. The power for a charging station could come from either an individual's house or a public building. A single centralized SCS or a network of individual charging stations can both serve as components of a public charging infrastructure. The MCS unit is portable, so you can charge your devices anywhere, inside or outside the FCS zone. Charging operations located outside the FCS region would be powered by energy stored in the MCS. There are more energy storage options for EVs than batteries and ultracapacitors. When compared to lithium-iron phosphate (LiFePO4) batteries, electric double-layer capacitors (EDLCs) perform better in MCS settings. Rapid charging is achievable when a battery is connected to an ultracapacitor, as their combined current and voltage can be maximized.

Decker et al.'s (2012) prototype technique for finding the most secure and easily accessible EV charging station was validated. Intelligent transportation systems (ITSs) and vehicle adhoc networks (VANETs) collect data on traffic conditions throughout the early stages of the Smart Grid [17]. Since hosting IT systems on the "cloud" allows for more easily transferable data, we choose to do so for this application as well.

Sun et al. (2016) [18] took use of limits on distribution transformer capacity to generate a valley-filling aggregate load profile and other desirable load distributions in the distribution grid. It is easy to convert this problem into a linear equivalent program because it is separable and totally unimodular. The second problem, with charging electric vehicles, is a direct result of people's efforts to resolve the first. The second issue is proven to be NP-hard, and an iterative solution is offered. Presently, the most comprehensive study of V2V power transfer between electric cars was conducted by Tiago et al. (2018). The conventional V2V mode can tap into an energy aggregator such as the electrical power grid by combining the V2G and G2V modes of operation. Two power converters (dc-dc and dc-ac) per battery bank are needed for on-board EV charging using the common V2V method. In the past, ac V2V has been prioritized above dc V2V, but this study expands our knowledge of the latter. The necessity for a central energy supply is mitigated by this technology, which allows electric vehicles to charge one other directly.

## III. BATTERY STORAGE SYSTEM

To hasten the installation of charging stations for electric vehicles, both the United States and the European Union have instituted incentive programs. To meet the charging needs of China's 6 million electric vehicles by 2025, the country will need to build more than 24,000 centralized charging and replacement power stations and more than 5.8 million scattered charging lots. There will surely be a tipping point in the next several years for the market for electric vehicles and the charging infrastructure that goes along with them. Users' safety and comfort are jeopardized by the line's location, the disorder it causes, and the fact that it has been there for decades.

Since humanity stopped using fossil fuel-powered internal combustion engines, there has been a discrepancy between the energy requirements of combustion engine replacements and what batteries can deliver.

Most of the cost of a modern electric vehicle goes toward the battery, and designers frequently choose optimal power handling above minimum range. Battery life can be reduced from a thousand to a few hundred charging and discharging cycles, as is often believed. Super-capacitors are well suited for high-power applications since they can withstand power loads up to 100 times that of lithium based batteries without suffering damage or shortening their lifespan. A minimum of 500,000 cycles is commonly seen in commercially available devices nowadays.

### Static and Dynamic Charging

Both the wireless charger and the electric vehicle need to be in close vicinity to the power grid, and the latter has to have some breathing room around it for the second coil. The electric vehicle is charged in a near-field fashion using the magnetic field generated by the wireless charger's transmitting coil. As the receiving coil takes in magnetic flux from the sending coil, it transfers that flux into usable power for the load. Both the signal and coil quality must be high for efficient data transfer.

### Inductive power transmission

Inductive power transmission (IPT) is one of two main types of wireless electricity transmission: When a car is detected in a parking garage or lot, the static IPT will go off. When the car is moving or has stopped short, like at a red light, the dynamic or quasi-dynamic IPT kicks in. Since cable charging is obviously not an option for EVs in motion, WPT is the only viable solution for dynamic or quasi-dynamic charging.

### Stationary Charging

The inductive 'pick-up' in the car accepts alternating current (AC) from the charging plate via a coil buried in the plate's magnetic field. The voltage converter changes the alternating current into direct current, which can then be used to charge the car's battery. A charging mat is placed on the floor next to a wall-mounted electrical socket. The road is now obstructed by a parked car. When the charger is within range of the trunk-mounted receiver, charging will commence automatically.

### Dynamically Charging

This technique allows electric vehicles to be charged while in motion, as opposed to the traditional stationary charging system, by means of a resonant coil. It is proposed by the government that charging lanes be built beside roadways so that drivers don't have to stop over to recharge their vehicles. Because dynamic charging cannot be provided through a wired system, WPTs are essential for any such system. Each hybrid bus has a wireless charging receiver installed. In order to charge a vehicle wirelessly, wireless chargers are embedded or buried at regular intervals in the road's surface. While waiting for the bus, devices will be connected wirelessly without having to run any cables. In other words, it will have charged on its own. To be more precise, it's a really busy bus. The United Kingdom, Italy, The Netherlands, and South Korea have all tried out these kinds of experimental buses.

- The convenience of not having to worry about plugging in a power source makes wireless options enticing.
- The device can be charged in a short amount of time.
- This configuration requires less room than a standard hardwired one.
- It's less bulky and more covert than a hardwired system.
- No live wires are exposed because there is no real connection.
- The risk of electrocution from utilizing corded equipment is eliminated.
- Newer WPT layouts are more effective than those before them.

## IV. WIRELESS POWER TRANSMISSION TECHNIQUE

Without the need for wires or other traditionally installed transmission media, energy can be sent wirelessly. This allows for the transmission of power to remote locations that conventional power lines cannot reach. Even though wireless charging for mobile devices isn't as fast as conventional charging, it does the job just fine. Meanwhile, the concept has made its way into our television remotes and climate controls. Using radio waves to transmit signals is a common practice in remote controls and has recently seen widespread application in electric vehicle charging systems (albeit in a variety of forms, which we'll get into later). Although there are various ideas for implementing wireless power transfer for EVs, the primary challenge in all studies on this topic has been the rate of the received signal efficiency [4].

The two most popular methods of wireless power transfer are far field and near field. Magnetic fields are used in near field, also known as non-radiative techniques, to transmit energy over small distances. When two metal electrodes interact capacitively, an inductive field is produced between the coils. Radiative or far field technologies include those like power beaming [9] that use highly concentrated beams of electromagnetic radiation.

### Inductive Coupling Technique

A transformer, formed by connecting the transmitter and receiver coils, makes magnetic field power transmission possible. Ampere's law states that the oscillation of the MF is caused by the AC that is generated and transmitted by the coil (transmitter). Here, a receiver coil is used to pick up the MF signal. In either case, the recipient will feel a current [10].

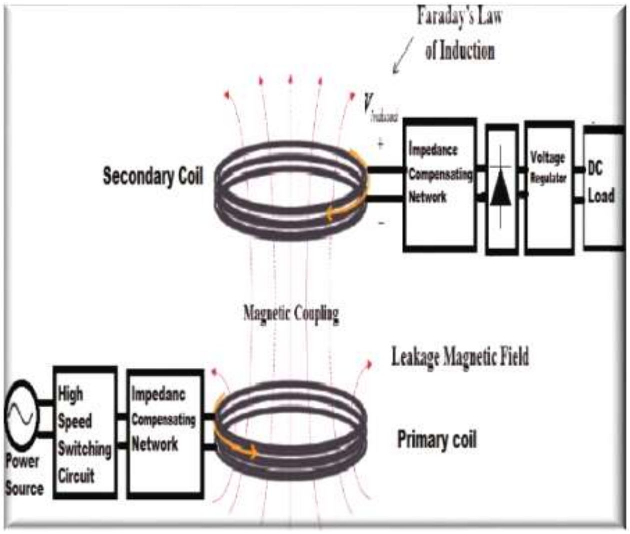

**Fig. 1** Mechanism of the inductive power transfer.

***Capacitive coupling technique***

Using a field as the signal transmitter between two electrodes (often an anode and a cathode) to generate a capacitance that enables the passage of power is similar to electric coupling. CC's high electrode voltage for transmitting electricity has relegated it to low power uses [11]. Each connected circuit's DC bias settings need not be the same for the connection to be effective.

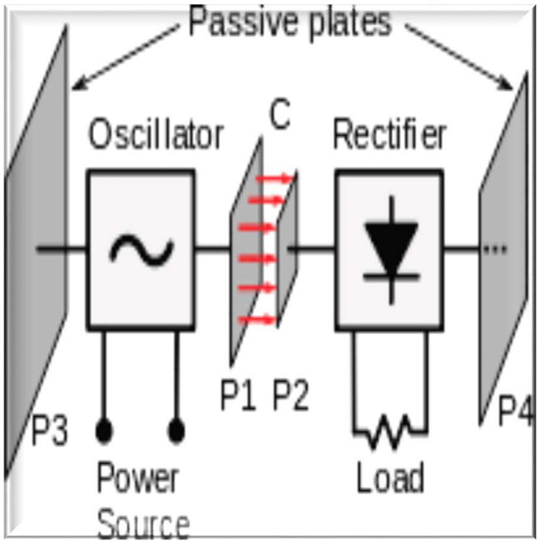

**Fig. 2** CC technique Reference.

Recent research has focused on capacitive power transfer due to its potential utility in situations calling for low-power transmissions across short distances.

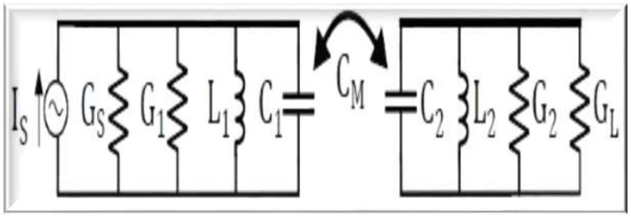

**Fig 3** Capacitive power transfer circuit.

**Far Field Techniques: Radio wave, Microwave and laser Techniques**

Two types of WPT have been compared in this article. Although an electromagnetic field and a far field would both benefit a wireless charging system for electric vehicles, the radio waves approach has the opposite characteristics in terms of distance and power, making it less likely to be implemented; furthermore, it makes use of the rarely-used capacitive power transfer technology [8]. The end product is significantly reduced EMI as compared to standard practice.

W.C. Brown was an early innovator in the field of microwave power transmission research between the years of 1939 and 1945. The decade of the 1960s was formative for him as a person [10]. In order to use radio waves to deliver electricity over great distances without utilizing wires, rectennas are required. Due to their shorter wavelength, radio waves are more efficient than conventional electricity.

The photonic cell needs to be pointed squarely at the laser so that it may absorb its energy. Using electromagnetic radiation, energy is "beamed" to its destination, where it is converted back into electricity via a specific receiver-side conversion (monochromatic light).

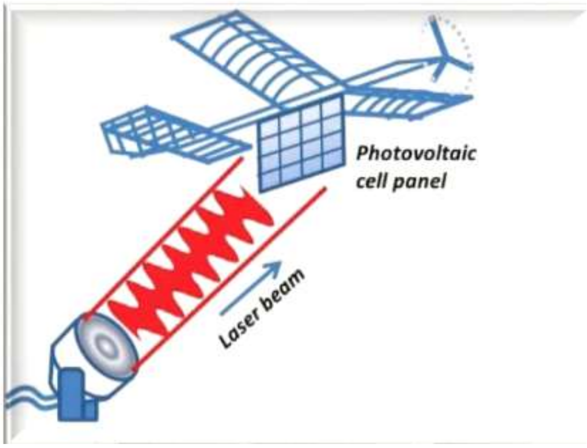

**Fig 4** Radio waves beaming.

These two methods of charging electric vehicles are said to be extremely efficient in this article. Distance is never a concern [12] because both may traverse great distances with minimum loss of quality throughout the transmission and reception procedures.

**Table 1.** Categories of WPT for EV charging system.

| **Energy Carrying Techniques** | | | **Power** | **Range** | **Efficiency** | **Concluding Remarks** |
|---|---|---|---|---|---|---|
| Electromagnetic Field | Near Field | Traditional Inductive Power Transfer Coupled | High | Low | High | Good for EV Charging System |
| | | Magnetic Resonance | High | Medium | High | |
| | Far Field | Laser, Microwaves Radio Waves | High | High | High | Direct line of sight is must in transmission, Tracking system is difficult, Limited Efficiency |
| Electric Field | Capacitive Power Transfer | | Low | Low | High | Power is small |
| Mechanical Force | Magnetic Gear | | High | Medium | High | Good for EV Charging Purpose |

## V. CONCLUSION

Everybody, from engineers to regular people, is starting to think about wireless power transfer. It is crucial to identify practical options for generating power. Wireless power transfer has many applications, including charging portable electronics and recharging electric car batteries. Before completely wireless systems can be employed in vehicles and other devices, a significant obstacle must be overcome: the development of a dependable wireless power transfer system. This will be accomplished if wireless power transmission becomes the norm. On-the-go recharging is possible with the help of a dynamic charging lane and, eventually, wireless charging points. Several countries, including the United Kingdom, Italy, The Netherlands, and South Korea, are now testing out prototype electric buses.

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