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# A Review on a High-Efficiency Wireless Power Transfer System with Intermediate Coils for the Chargers of Electric Vehicles

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**Abstract**

Wireless Power Transfer (WPT) devices are able to move electricity from its source to its load. WPTs have several benefits over their wired cousin, making them desirable for usage in many industrial applications. Some businesses are looking at using WPTs to charge the batteries of electric vehicles (EVs), and research and development is being done to better the different topologies involved. In recent years, WPT technology has seen significant advancements According to these enhancements, the WPT is more appealing for use in stationary and dynamic EV charging applications. In this study, we took a look at the WPT field and all the technologies that may be used to wirelessly charge an EV. The challenges of charging time, range, and cost are readily solved by using WPT in EVs. There is no longer a need for advancements in battery technology for EVs to gain widespread consumer acceptance. Researchers are pleased by the state-of-the-art accomplishments and are expected to continue developing WPT and expanding EV.

**Keywords:** ***Dynamic charging, electric vehicle (EV), inductive power transfer (IPT), safety guidelines, stationary charging, wireless power transfer (WPT).***

## 1. Introduction

The process of electrifying transportation has been ongoing for quite some time for a variety of reasons, including energy efficiency, environmental friendliness, and convenience. The electric locomotives used on railroads have been extensively refined for decades. A train follows a set path, or track. Using pantograph sliders, obtaining electricity from a conductor rail is simple.[1] However, the high adaptability required by EVs makes it more difficult to get power in a comparable fashion. Instead, a high-power, high-capacity battery pack is often installed as the EV's energy storage unit, allowing it to go a respectable distance between charges.[2][3]

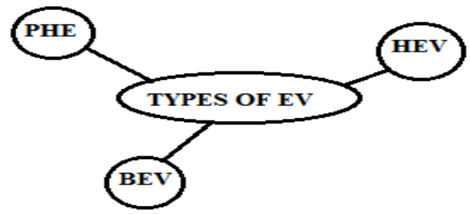


Fig. 1: Types of EV battery chargers

There are three distinct categories of electric vehicles (EVs), each corresponding to a different level of power consumption. Vehicles that run only on electricity, such as battery electric cars, plug-in hybrids, and hybrids, are becoming more common (HEV). Only BEVs have access to the fastest charging option, a level 3 DC rapid charge.[4][5]

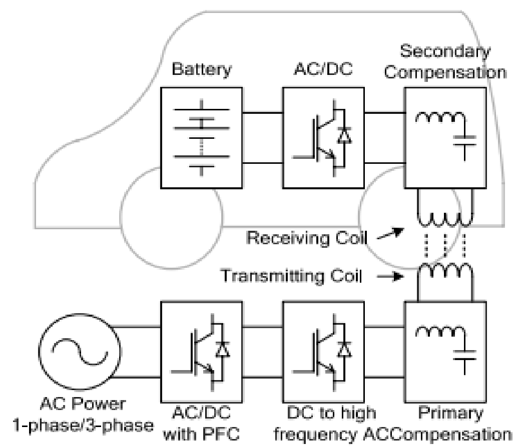


Fig. 2: Typical wireless EV charging system.

Electric vehicle (EV) owners want wireless power transfer (WPT) technology because of its potential to solve their charging problems. Charging an electric vehicle (EV) is simplified by making use of wireless energy transmission. Drivers may leave their vehicles at a fixed WPT facility. With a dynamic WPT system, the EV could be charged as it drove, making limitless operation feasible.[6][7]

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Table 1: Different Wireless Power Technologies

| Technology | Range | Directivity | Frequency | Antenna devices | Current and/or possible future applications |
|---|---|---|---|---|---|
| Inductive coupling | Short | Low | Hz – MHz | Wire coils | Electric tooth brush, razor battery charging, induction stovetops, industrial heaters. |
| Resonant inductive coupling | Mid- | Low | kHz – GHz | Tuned wire coils, lumped element resonators | Charging portable devices, biomedical implants, electric vehicles |
| Capacitive coupling | Short | Low | kHz – MHz | Metal plate electrodes | Charging portable devices, Smartcards, |
| Magneto dynamic coupling | Short | N.A. | Hz | Rotating magnets | Charging electric vehicles, biomedical implants. |
| Microwaves | Long | High | GHz | Parabolic dishes, phased array | Solar power satellite, powering drone aircraft, charging wireless devices |
| Light waves | Long | High | ≥THz | Lasers, photocells, lenses | Charging portable devices, powering space elevator climbers. |

## 2. Literature Review

M. H. Ameri, A. Y. Varjani and M. Mohamdian et al. [1] in various applications, like IPTEC, any variation in alignment and distance between pickup and charger, primarily leads to a change in leakage and magnetic impedance magnitudes. Because of these variations the power transmission capacity is not always at the maximum level. This study proposes a new low-cost tracking method that achieves the Maximum Inductive Power Transmission Capacity (MIPTC). Also the proposed method does not require the exchange of information between load and source.

T. D. Nguyen, S. Li, W. Li, and C. C. Mi et al. [2] presents the feasibility study of bipolar pads for extremely high efficiency wireless battery chargers used in electric vehicle (EV)
and plug-in hybrid electric vehicle (PHEV) applications. Due to the unconventional flux distribution in this system, a 3D finite element method is employed for its design and analysis. The importance of misalignment tolerance in this system is analyzed and discussed. The distinct features of rectangular bipolar topology is been exploited to develop the pads for wireless battery chargers for EV applications.

J. H. Kim et al. [3] Design and fabrication of a 1-MW inductive power transfer (IPT) system which supplies power to the vehicle in real time without any battery charge is proposed for a high-speed train. The IPT system consists of a 1-MW resonant inverter, a 128-m transmitter, four pickups, including rectifiers and a wireless feedback network to maintain a constant output voltage of the pickups. The operating frequency of the system is 60 kHz to achieve efficient power transfer with a large air gap. The measured efficiency of the IPT system at the 818-kW output power of the pickups for the 5-cm air gap is 82.7%.

Y. Nagatsuka, N. Ehara, Y. Kaneko, S. Abe, and T. Yasuda et al. [4] Electric vehicles are attracting considerable interest recently. A contactless power transfer system is required for EVs. Transformers can have single-sided or double-sided windings. Transformers with double-sided windings are expected to be more compact and lightweight than transformers with single-sided windings. A contactless power transfer system for EVs needs to have a high efficiency, a large air gap, good tolerance to misalignment and be compact and lightweight. This paper proposes, a novel transformer using series and parallel capacitors with rectangular cores and double-sided windings that satisfies these criteria and its characteristics are described. It has an output power of 1.5 kW and an efficiency of 95% in the normal position. To reduce the cost of expensive ferrite cores, a transformer with split cores is also proposed.

A. Pevere, R. Petrella, C. C. Mi, and Shijie Zhou et al. [5] the technology of wireless charging, also referred to as wireless power transfer (WPT) or inductive power transfer (IPT), has been successfully applied at the low power level applications , such as in the medical field or in small devices like smart phones. Along with the fast growing interest in electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs), wireless charging is becoming a new way of charging batteries.

G. Covic and J. Boys et al. [6] the Inductive Power Transfer (IPT) has progressed to become a power distribution system offering major benefits in modern automation systems and particularly so in harsh environments. This paper evaluates the development of simple factory automation (FA) IPT systems for both today's complex applications and onward to a much more challenging application-IPT roadway. The foundation of all IPT technology is two strongly coupled coils operating at resonance to efficiently transfer power. Over time the air-gap, efficiency, coupling factor, and power transfer capability have significantly improved. New magnetic concepts are introduced to allow misalignment, enabling IPT systems to migrate from overhead monorails to the floor. However, the demands of IPT roadway bring about significant challenges.

J. Deng, J. Deng, W. Li, S. Li, and C. Mi et al. [7] this paper presents a novel magnetic integrated LCC series-parallel compensation topology for the design of both the primary and pickup pads in inductive power transfer (IPT) applications. A more compact structure can be realized by integrating the inductors of the compensation circuit into the coupled power-transmitting coils. The impact of the extra coupling between the compensated coils (inductors) and the power-transferring coils is modeled and analyzed and the basic characteristics of the proposed topology are studied based on the first harmonic approximation (FHA). High-order harmonics are taken into account to derive an analytical solution for the current at the switching instant, which is helpful for the design of soft-switching operation.

T. Shijo, K. Ogawa, and S. Obayashi et al. [8] Transmitting and receiving resonators for 7 kW-class wireless power transfer/transmission (WPT) systems operating at 85 kHz have been developed for contactless Electric Vehicle (EV)/Plug-in Hybrid EV (PHEV) charging. The light weight and small volume of the on-board receiving resonator to be mounted on the vehicle are required attributes. The thickness and shape of the core in the resonance coil are optimized considering a coil weight, a core loss and a coupling coefficient between the resonators.

## 3. Proposed Methodology

Magnetics, power electronics, communications, mechanical engineering, and electrical engineering are only few of the fields that contribute to WPT. Due to the system's transdisciplinary character and inherent uncertainties, studying a WPT system may be a challenging endeavour.It is possible to bring this study up-to-date by simulating the Wireless Power Transfer System used to charge the batteries of electric vehicles. The PI controller's major function is to regulate the charging current by adjusting the duty ratio of the switches on the primary side of the high frequency transformer. There are two inputs to fuzzy processing: an error and an error change. A fuzzy controller uses a set of language rules to regulate its actions. Since no mathematical model is necessary, it may be used with erroneous inputs. [3]

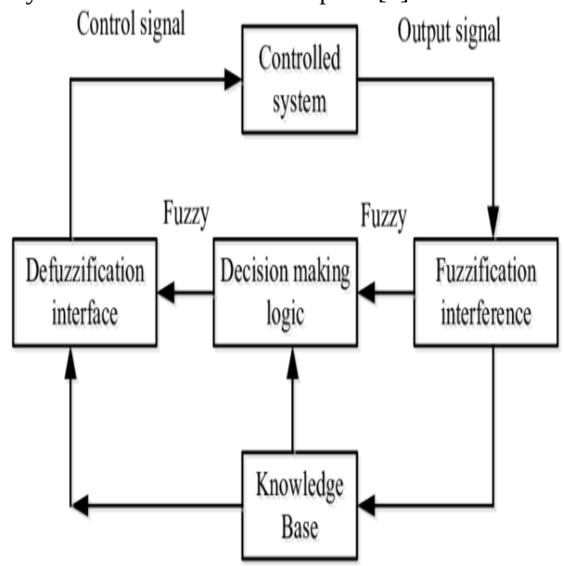


Fig.3 Block diagram of Fuzzy Logic Controller

### *3.1Advantages of Fuzzy Logic Controller*

The following are the benefits of fuzzy control over other adaptive control methods:

System design can be improved since it doesn't need to know all the variables, allowing for more precision.

The language, rather than the numerical, elements make the process resemble that of logical cognition.

Due to their ability to handle a wide range of operating conditions, they are more robust than PI controllers.

FLC is cost-effective.

FLC is adaptable.

FLC is a trustworthy company.

FLC is more efficient.

It improves stability.

The Mamdani fuzzy controller outperforms the PI controller; however, it comes with the drawback of a higher number of fuzzy sets and rules. Additionally, in order to surpass the typical PI controller, all of the coefficients must be increased. The fuzzy control system requires less time to settle than the PI control system and FIS system.

## 4. Conclusion

Wireless charging for EVs was the topic of this research report. The environment and energy crisis have made it abundantly evident that the electrification of vehicles is inevitable. In comparison to the current wired charging methods, wireless charging will have several advantages. Specifically, when highways are electrified with wireless charging capabilities, it will pave the way for widespread adoption of EVs regardless of battery type. Improved wireless charging for EVs is feasible with current technological trends. New research is urgently required in the fields of topology, control, inverter design, and human safety. Future applications may make use of controllers such as PI, DSM-PI, which allow for more rapid regulation and stabilisation of battery current, hence reducing reaction time.

Various scholars continue to provide novel answers to the problems in the area every year, and some of them are briefly discussed here to show how they have boosted the field. The electrification of transportation will undoubtedly spur the development of WPT as a practical option for electrically propelled mobility. There is a fast-expanding group of researchers in both academia and business focusing on WPT for EVs.

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