

# Review on Enhanced EV technology: Wireless charging system and performance improvement with MLI

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**Abstract** - Electric vehicle research has been advanced in several nations in order to lessen reliance on oil and environmental pollution. The implementation of EVs, especially battery electric vehicles, is considered a solution to the energy crisis and environmental issues. This paper provides a comprehensive review of the technical development of EVs and emerging technologies for their future application. In addition, the energy crisis and the low energy efficiency of conventional vehicles also offer a good opportunity to develop electric vehicles. Today, many recent developments focus on improving electric vehicles and their components, particularly regarding advances in batteries, energy management systems, autonomous features, and charging infrastructure. In current times wireless charging system of electric vehicle technology is trending and in several countries, there is a lot of work done on multilevel inverters for improving the performance of electric vehicles.

**Key Words:** Electric Vehicles, Wireless charging system (WCS), Multilevel inverter (MLI), Total harmonic distortion (THD), Series-Series compensation

## 1. INTRODUCTION

Energy and environmental problems have been brought on by the growing number of internal combustion cars that use non-renewable conventional fuels [1]. Since traditional automobiles generate air pollution and oil dependence, many nations have adopted new energy vehicles (NEVs) as alternatives [2].

India produced 3202 million metric tonnes of carbon dioxide equivalent in 2014, providing for 6.55% of the world's overall emission of greenhouse gases. Energy-related activities account for 68% of greenhouse gas emissions in India, with agriculture, industry, better land use and forestry practices, and waste contributing an additional 19.6%, 6.0%, 3.8%, and 1.9% [3]. By 2030, India wants to have 30% of its private cars electric and all of its public transportation to be electric [4]. One of the major choices made during the Global Mobility Conference in New Delhi was this. More than 70% of pollution is produced by the transport industry, which uses 70% of all fossil fuels. The Government provides a lower GST at 12% on electric vehicles while the Government levies 28% GST plus cess for petrol and diesel cars [5].

Because of the low production of EVs, their entire market share in India is quite small. The Reva Electric Car, the country's first electric vehicle brand, introduced its model in the early 2000s with an emphasis on producing cheap vehicles using advanced technology [6].

In this review paper, we focused on the performance of EVs which is related to inverters, and also discussed the wireless charging technology for EVs. Wireless charging technology for EVs is a great idea for safety purposes. The wireless charging system has two types, static wireless charging system, and dynamic wireless charging system. There will be various advantages to wireless charging over wired charging. The operating costs are reduced, but the initial investment is highly significant [7].

In India, the Mumbai-based startup PMV has unveiled its first electric vehicle. The nano-sized EV, known as the EaS-E, is now the most reasonably priced electric vehicle in India [8].

In this paper, we review the impact of Multilevel inverters on EVs. We discussed which factors will vary or improve in EVs with the help of MLI. The factors which vary with using MLI is like total harmonic distortion, efficiency, losses, etc.

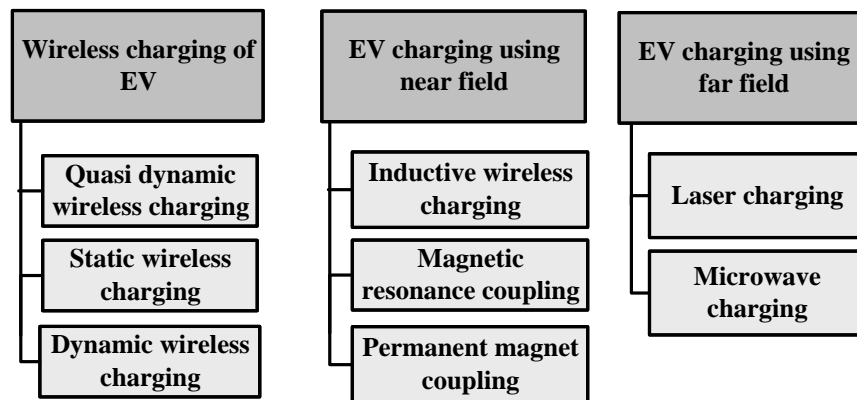


Figure 1: Types of wireless charging and different EVs charging method

## 2. Methodology:

In this paper, we have reviewed the electric vehicle new technology and performance which is based on the inverter's Total harmonics distortion (THD). The new technology discusses along with a wireless charging system (WCS) for electric vehicles. WCS of electric vehicles is a very trending topic in recent times for researchers.

This paper is divided into six sections. Review of multilevel inverter and wireless charging system in first section. Section III consists of, Country which implemented a wireless charging system. This section also consists the classification and comparison of different WPT technology for EV charging and a summary of the wireless EV charging project. Section IV consists of, Impact and uses of MLI in EVs this section contains the application of MLI and its advantages in EV application. In section V, consists of different types of EV charging standards. In last section VI, it consists discussion and conclusion of this paper.

So, basically in this review paper, we discussed advantages of MLI, the benefits of WCS for EVs, and also discussed various technology for charging EVs.

## 3. Country which implemented wireless charging system:

In an attempt to develop a zero-emission taxi system by as early as 2023, Oslo will become the first city in the world to implement WCS for electric taxis [9].

The idea is to make charging electric taxis as simple as possible because it is now difficult, expensive, and time-consuming. The taxis can be charged while they wait in what is known as a taxi rank, or a long line of cabs waiting for customers, using induction, a more energy-efficient charging method. The cabs will be equipped with charge receivers. The cabs can then be charged for up to 75 kW using charging plates that have been installed in the ground. The average power of the current AC chargers is 22 kW [10].

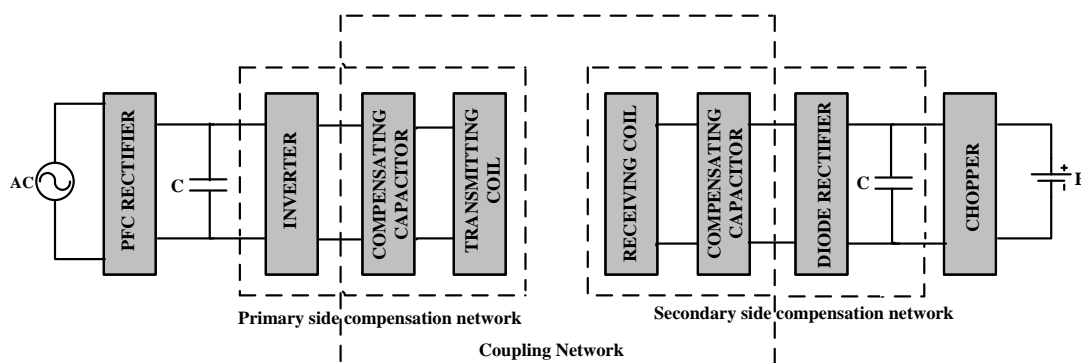


Figure 2: Block diagram for wireless power transfer

There are several types of wireless power transfer technology, which are mentioned in Table 1 and also discussed their power, efficiency, and range of WPT.

Table 1. Classification and comparison of different WPT technology for EV charging [11]

Energy-carrying medium	Technology		Power	Range	Efficiency	Comments
Electromagnetic field	Near field	Traditional IPT	■	◇	■	The range is too small for EV charging
		Coupled Magnetic resonance	■	□	■	Capable for EV charging
	Far-field	Laser, Microwave	■	■	■	Need a direct line of the sight transmission path, large antennas, and a complex tracking mechanism
		Radio wave	■	■	◇	Efficiency is too low for wireless charging
Electric field	Capacitive power transfer		◇	◇	■	Both power and range are too small for EV charging
Mechanical force	Magnetic gear		■	□	■	Capable for EV charging

■-High, ◇-Low, □-Moderate

Many countries in the world are currently working on the wireless charging technology of EVs and they are working on several projects described in Table 2, which consist location of the project, power, air gap, and efficiency of wireless charging of EVs. Table 3 consists of the EV battery information and power transfer level comparison of charging methods. Table 4 consist of various type of feature with charging technology.

Table 2. Summary of wireless EV charging project [11]

Institute / Corporation	Year of installation	Location	Project Type	Vehicle Type	Power	Air gap	Efficiency (%)
Auckland University & Conductrix-Wampfler	1997	Auckland	Public Demonstration (Stationary)	5 Golf Buses	20kW	50mm	90-91
	2002-2003	Italy		8-23 mini buses	60kW	30mm	-
Auckland University & Qualcomm Halo	210	Auckland	Evaluation kits (Stationary)	Private vehicle	3kW	180mm	85
	2012	UK	Public demonstration (Stationary/ Dynamic)	-	-	-	-
ORNL	2010	US	Prototype (Dynamic)	-	4.2kW	254mm	92(coil-to-coil)
	2012	US	Prototype (Stationary)	-	7.7Kw	200mm	93%(coil-to-coil)
	2012	US	Prototype (Stationary/ Dynamic)	GEM EV	2kW	75mm	91(coil-to-coil)
KAIST	2009	Korea	Prototype (Dynamic)	Golf bus	3kW	10mm	80
				Bus	6kW	170mm	72
	2010	Korea		SUV	17kW	170mm	71
	2012	Korea	Prototype Demonstration (Dynamic)	Tram	62kW	130mm	74
Bus				100kW	200mm	75	

MIT WiTricity & Delphi	2010	US	Commercial kits (stationary)	Private vehicles	3.3kW	180mm	90
Evatran	2010	US	Commercial product (stationary)	Private vehicles	3.3kW	100mm	90

Table 3: EV battery information and power transfer level comparison of charging methods [12]

Model	Battery	Wallbox charging time	Box charging time
Peugeot e-208	50 kWh, range:211 miles	5 hrs (11kW)	30 mins to 80% (100kW)
Mercedes EQC	80 kWh, range:280 miles	12 hrs (7.4kW)	40 mins to 80% (100kW)
Audi e-tron	95 kWh, range:248 miles	9 hrs (11kW)	30 mins to 80% (150kW)
BMW i3	42.2 kWh, range:160 miles	4 hrs (11kW)	42 mins to 80% (50kW)
Citroen C-Zero	14.5kWh, range:93 miles	7 hrs (3.7kW)	30 mins to 80% (50kW)
Hyundai Loniq Electric	28kWh, range:174 miles	4.5hrs (7.4kW)	25 mins to 80% (50kW)
Jaguar I-Pace	90kWh, range:292miles	13hrs (7.4kW)	45 mins to 80% (100kW)
Kia-e-Niro	64kWh, range:282miles	10hrs (7.2kW)	45 mins to 80% (60kW)
Nissan Leaf	40kWh, range:168miles	7hrs (6.6kW)	40 mins to 80% (50kW)
Tesla Model 3	75kWh, range:338miles	5hrs (11kW)	30 mins to 80%(120kW)
Tesla Model S	100kWh, range:393miles	7hrs (16.5kW)	40 mins to 80%(120kW)

Table 4: Comparison of Plugless, Qualcomm Halo, and WiTricity [12]

Features	Plugless Power	Qualcomm Halo	Witricity (DRIVE 11)
Technology	Inductive Charging	Resonant magnetic inductive	Magnetic resonant coupling
Normal charging gap	4 in (10cm)	No mind the gap (high energy transfer over a wide air gap)	Low:10cm-15cm Med:14cm-21cm High:17cm-25cm
Standards	NEC 625 (NFPA 70) SAE J1772,UL 2231 and CSA 170.1	ISO, IEC and SAE	SAE TIR J2954, IEC and ISO
Power transfer rates	GEN 1 system: 3.3kW-7.2kW GEN 2 system:7.2kW	3.3kW-6.6kW	WPT 1: 3.6kW WPT 2: 7.7kW WPT 3: 11kW
Efficiency	3.3kW output with 10cm gap:88.8%	Greater than 90%	Up to 90% grid to battery
Test	GEN 1 system: Chery Volt, Nissan LEAF GEN 2 system: Tesla Model S, BMW i3	3.3kW and 6.6kW:Delta E-4 7kW:Rolls Royce Phantom 102EX 20kW:Drayson B12/69	Delphi Automotive
Others	Get 20-25 miles of range/hour parked	Power transfer solution have been developed to suit a broad range of vehicle type	Parking freedom: X-Y-Z

#### 4. Impact and uses of MLI in EVs:

Due to their outstanding qualities, MLI is attracting interest in several medium- to high-power, high-voltage applications. MLI has a number of key benefits, including less electromagnetic interference, higher power quality, and less voltage stress and loss of each individual semiconductor component [13]. MLI solutions are preferred in these applications due to the increased power and input voltage in electrified trains, tramways, and ships. The MLI is also used to improve the efficiency of EVs and increase their reliability of EVs. The output percentage of THD nears zero as the number of levels increases to infinity, but the cost of implementing the higher level increases significantly [20]. There is one demerit of MLI is the cost of the system increases as compared to the single-level inverter. MLI has the capability that it can operate without transformers hence it enabling transformer less operation.

It is common for MLI to have a modular structure. Due to its modularity, the system offers greater voltage and current capabilities [16]. Table 5 shows the maximum DC voltage and the conventional structures in different traction applications.

Table 5. Traction Inverter`s structure in the market [9]

Application	DC Voltage (V)	Structure	Switching devices
Electric ships	1.5 kV – 15 kV	2-level or multilevel	GTO, Thyristor, or IGBT
Trains and Tramways	up to 3 kV	2-level or three-level	GTO, Thyristor, or IGBT
Buses, Trucks	up to 900 V	2-level	IGBT, MOSFET
Passenger Evs	up to 900 V	2-level	IGBT, MOSFET

#### 5. EVs charging standards:

Many worldwide standards include EV charging infrastructure. While IEC is widely utilized used in Europe, SAE and IEEE are used by manufacturers based in the United States. Japan has its EV charging standard named CHAdeMO. China uses the Guobiao (GB/T) standard (issued by the Standardization Administration of China and the Chinese National Committee of ISO and IEC) for AC and DC charging, where GB/T AC charging standards are similar to IEC standards. Table 6 consist wireless charging standard and published year.

Table 6: Wireless Charging standard [14-15]

Standard developer	Standard Name	Published Year	Description
IEC	IEC 6180-1Ed.1.0-New Addition	2015	Electric vehicle WPT system Part 1: General Requirement
IEC	IEC 61980-1Ed.2.0	2020	Electric vehicle WPT system Part 1: General Requirement
IEC	IEC 61980-1/IAMD I Ed1.0	2015	Electric vehicle WPT system Part 1: General Requirement
IEC	IEC 61980-1/COR1A	2017	Electric vehicle WPT system Part 1: General Requirement
IEC	Draft IEC/TS61980-3Ed1.0	2015	Electric vehicle WPT systems Part3: Specific Requirements for the magnetic field power transfer system
SAE	J2954SAE	WIP	Wireless charging Electric and Plug in Hybrid vehicles
SAE	J2954_201605	2016	WPT for light duty plug in /Electric vehicles and Alignment methodology

SAE	J1773_201406	2014	SAE electric Vehicles inductively coupled charging
SAE	J2847-6	2015	Communication between Wireless charger charged vehicles and wireless EV Chargers
SAE	J2831	2015	Signaling Communication for wireless charged Electric vehicle
UL	Subject 2750	NA	Outline of Investigation for Electric Vehicle wireless charging
SAE	J2836/1-2	NA	Use Cases for Communication Between Plug-in Vehicles and the Utility Grid, and Plug-in Vehicles and Off-Board DC Charger, respectively.
SAE	J2836/3	NA	Use Cases for Plug-in Vehicle Communication as a DER.

Table 7: Efficiency of compensation topologies [18-19]

Compensation topologies	Efficiency (%)
Series-Series (SS)	98.72
Series-Parallel (SP)	94.6
Parallel-Series (PS)	60
Parallel-Parallel (PP)	65

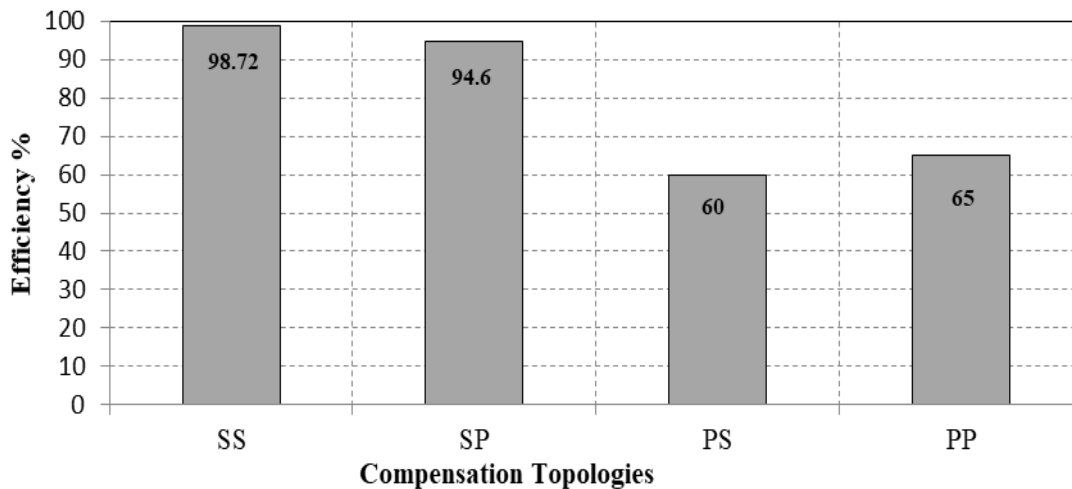


Figure 3: Efficiency of compensation topologies

## 6. Discussion/Conclusion:

In this review paper, we have discussed emerging and enhanced EVs technology with multilevel inverters (MLI) and wireless power transfer systems with different types of topologies and we used a highly efficient topology so that the EVs model has high efficiency and greater reliability. The WPT topologies are four types which are Series-Series (SS), Series-Parallel (SP), Parallel-Series (PS), and Parallel-Parallel (PP). In these topologies, the SS topology has greater efficiency, so in EV charging, we use the SS topology. In terms of the emerging technology of EVs, the wireless charging system is the most interesting and highly recommended topic and when we discussed the efficiency of the system we focused on the minimization of losses. By using MLI, total harmonic distortion will be less, so the efficiency and performance of the system will be increased.



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