Wireless Power Transfer for Electric Cars

Dr. S. Muthukumar[1], Deepika .K.P[2], Gayathri .B[3], Haripriya .S [4]

[1]Professor and Head, Dept of ECE Sri Venkateswara College of Engineering, Sriperumbudur, TamilNadu
[234]Students of Electronics and Communication Engineering, Sri Venkateswara College of Engineering, Sriperumbudur, TamilNadu

---

Abstract— *The demand for electric vehicles is rising, which ultimately results in an increase in the number of charging stations. In this project, the vehicle is wirelessly charged via inductive coupling, and payment is made using RFID technology. This project helps tackle the issue of building independent charging stations. Instead, this system can be incorporated in places like malls where people tend tospend longer, and thus parking time can be efficiently converted to charging time. The technology known as wireless power transfer (WPT) employing inductive coupling has the potential to relieve people from obtrusivewires. Additionally, a person can use the RFID tag to pay for the charging costs of that vehicle through the Internet of Things-based collection system that is designed. The system determines if the user has enough money in their account before taking the necessary deductions and updating the balance. No human interaction is necessary for this system. Along with a DC motor that will serve as a gate opener, we also used IR sensors to check for open slots. To track the vehicles that were charged at the stations, a web application was also created.*

Keywords— Wireless Power Transfer, IoT, RFID, Smart Parking System, Android Application

1. INTRODUCTION

New technologies are always being developed in the field of technological innovation to make living easier. To charge electric vehicle, we still rely on the classical and conventional wire system. Wired charging systems has problems like when numerous electric vehicles are being charged at once, the traditional wiring system becomes a mess. They need bulky charging connectors and cords. Additionally, the charger needs to be manually linked. Lethal electric shocks could be caused by a short circuit or by the insulation of the charging cable failing because of conditions like high temperatures, ground contact, or the charging device itself.

To reduce charging time huge number of batteries can be employed, or the depleted batteries can be swapped out for the charged batteries as needed. The batteries, however, have their own set of issues. The batteries are expensive initially, hefty, and have a short lifespan. Future advancements in energy storage technology might make it possible to solve these issues. The WPT is yet another approach that might be used to get around the batteries' issues. Moreover, the manual plugged in charging systems' trouble with wires and connectors is eliminated by the WPT approach, making it convenient.

Wireless power transfer (WPT) allows electric vehicles (EVs) to recharge their batteries without using a physical connection to a charging station. This technology offers several advantages over traditional wired charging, including greater convenience and reduced wear and tear on the vehicle's charging port.

By enabling wireless charging, WPT technology can help increase the adoption of EVs by reducing the hassle and inconvenience of plugging and unplugging cables and by providing a more seamless and user-friendly charging experience. Additionally, WPT technology has the potential to increase the range of EVs by enabling dynamic charging while driving or parked, reducing the need for frequent stops at charging stations.

RFID is used to make payments easier and safer. The self- operated gate at entry and exit is implemented using an IR sensor and a servo motor. Electric vehicles can be controlled using an Android application, which makes parking accurate.

2. LITERATURE REVIEW

M. Ahmed and O. O. Khalifa introduced a distinctive approach to wireless charging in their work titled "Wireless Power Transfer for Electric Vehicle Charging." They conducted tests under different conditions, evaluating distance and alignment, and achieved an impressive efficiency rate of 90%. Emphasizing the critical role of coil design, their findings underscore the significance of optimizing this component [1].

Addressing parking-related challenges,Denis Ashok, Akshat Tiwari, and Vipul Jirge developed a "Smart Parking System using IoT Technology." By harnessing the power of the Internet of Things (IoT), their system creates a well-organized parking environment. Users are seamlessly directed to available parking spaces through illuminated indicators, eliminating the need for time-consuming searches. The system's automated nature also reduces labor requirements, enhancing efficiency [2].

To enhance power transfer efficiency in electric vehicles, R. Kavin, V. Koushika Gowri, M. Naveenaa, T. Navishree, and J. Nithish proposed a novel approach titled

"Wireless Power Transmission in Electric Vehicles Using Solar Energy." Their method incorporates MOSFET switches in the inverter to improve coil performance and achieve faster and more efficient charging. By leveraging higher frequencies, this approach enhances the overall driving experience of electric vehicles, addressing challenges related tocharging time, range, and cost [3].

Another noteworthy contribution to smart parking systems comes from Yash Agarwal, Punit Ratnani, Umang Shah, and Puru Jain, who developed an "IoT-based smart parking system." Their solution involves a user-friendly mobile application that provides real-time information on nearby parking lots, including availability status. Users can conveniently reserve a parking spot through the app and authenticate their access using RFID technology upon arrival. This IoT-based approach significantly improves efficiency, reliability, and convenience while optimizing the utilization of parking resources [4].

Zamani, M. Nagrial, J. Rizk, and A. Hellany conducted a comprehensive review titled "A review of inductive power transfer for electric vehicles." Focusing on inductive coupling, their review encompasses the fundamental principles of inductive power transfer and offers an overview of state-of-the- art wireless power transfer systems for electric vehicles. This work contributes to the understanding and advancement of inductive power transfer technologies in the context of electric car charging [5].

3. EXISTING PROBLEM

The current wireless charging electric vehicle model has a receiving pad that is mounted on the underside of the vehicle and a charging pad that is normally installed on the ground at a parking area. The two charging pads electronically communicate when the car is parked on top of one of them to transmit electricity to the battery. The installation and positioning of the necessary WPT parts, such as the transmitter coils, receiver coils, and power electronics, might be challenging due to the constrained space in parking slots. The installation and use of WPT systems in parking infrastructure could have regulatory and safety implications. There may be concerns about electromagnetic interference or radiation, as well as issues related to standardization and interoperability of WPT systems across different makes and models of EVs.

4. CHARGING PROCESS

There are two modes for charging the EV batteries. In one configuration, the charging voltage may change while the charging current remains constant. The constant current (CC) charge is the term used to describe it. The other option allows the charging current to fluctuate while maintaining a constant charging voltage. The term "constant voltage" (CV) charge" refers to this.

CC mode is utilised to begin the process of charging a depleted battery. Typically, the charging current is kept at around 10% of the battery's rated capacity. The CV mode is then utilised to charge the battery as soon as the battery SoC gets close to its rated capacity, let's say 75%. This guarantees a straightforward charging procedure without overheating and battery damage.

A strong charging current may arise if the CV mode is used to start charging a depleted battery, which could cause the battery to overheat or get damaged. Thus, CV mode is not employed when a battery is charged charged to less than 75% of its capacity. When a battery is charged closer to its rated capacity using CC mode it results in overcharging which could overheat the battery or battery gets damaged.

PWM and PFM are two modulation methods that can be applied to constant-duty converters to handle load changes. PWM and PFM can both be utilized as modulation techniques as opposed to only one.

5. OVERVIEW OF BATTERIES

Typically, electric vehicles are parked either at residences or storage facilities. To charge the vehicle, the battery charger is connected to a domestic single-phase AC socket, allowing for slow overnight charging. The duration of the charging process varies depending on factors such as battery capacity and depth of discharge, but it generally takes around 7 to 9 hours, with a maximum charging current of 14 A.

Battery chargers play a crucial role in the advancement of electric vehicles. The charger's parameters have an impact on both charging time and battery lifespan. A reliable and efficient battery charger is required, with considerations for low cost, small size, and light weight. Additionally, an EV charger must ensure minimal distortion and a high power factor when drawing current from the utility, aiming to minimize the impact on power quality and maximize the available real power from the utility outlet

5.1 LEAD-ACID BATTERIES

Lead-acid batteries are widely available and have a proven, economical, and reliable manufacturing process. However, concerns arise regarding their disposal and the need for effective pollution control to reduce emissions during recycling. These batteries, due to their larger weight, are not suitable for portable applications.

5.2 NICKEL METAL HYDRIDE BATTERIES

Nickel metal hydride batteries offer a higher energy density. With an energy density of approximately 70 Wh/kg, they have been utilized in various all-electric plug-in vehicles. They have also found applications in hybrid vehicles. toxic These batteries generally have a lower environmental impact as they do not contain cadmium.

5.3 LITHIUM-ION BATTERIES

Lithium-ion batteries are highly preferred for electric cars due to their superior range per charge. They are also less expensive than nickel-metal hydride batteries and have a low discharge rate. To extend the lifespan of lithium-ion batteries, it is recommended to charge them early and often, avoid depleting them below their minimum voltage, and keep them cool. Table 1 compares different battery chargers.

Table 1: Comparison of Batteries

Parameters	Lead acid	NiMH	Li-ion
Nominal cell voltage(V)	2.2	1.1	3.65 – 3.75
Specific energy (Wh/kg)	30 – 40	60 – 120	150 - 250
Specific power (W/kg)	180 - 240	300 - 900	1500 - 3000
Energy density (Wh/l)	50 – 90	140 - 300	250 - 700
Charge/ Discharge efficiency (%)	70 - 92	66 - 70	95 - 98

6. COIL PARAMETERS

6.1 COIL RESISTANCE

The greatest impediment to the delivery of power in WPTS is the resistance of the primary and secondary coils. Consequently, figuring out their resistance is essential. The transformer's efficiency would actually be 100 percent if resistances were zero. The joule effect that coil resistances cause must be contained within allowable limits. Because of this, joule losses must be kept to a minimum when building WPTS in order to maximize efficiency and transferred Power.

6.2 MUTUAL INDUCTANCE

When a change in current in one coil causes an emf in a different coil close by the first coil, mutual inductance occurs. For the design of the WPT system, this parameter is the most reliable.

6.3 SKIN EFFECT

The center of a conductor made up of one or more concentric circular pieces will have a larger magnetic flux surrounding it than the outer parts. There will be a variation in current density between the conductor's center and surface as a result of the self-induced back EMF being stronger towards the conductor's center. The skin effect, which is caused by this additional concentration at the surface, raises the conductor's effective resistance.

6.4 PROXIMITY EFFECT

The proximity effect, which is linked to the magnetic fields of two conductors that are adjacent to one another, also causes an increase in effective resistance. The remote half of the cross-section therefore carries a higher share of the current distribution, which is not uniform over the cross- section. The portions that are close together will carry a higher current density if the currents are flowing in opposing directions.

7. PROPOSED SOLUTION

To overcome the problem, we have incorporated WPT technology into already-existing parking facilities, including parking garages, retail centers, theatres, and jewellery stores, among others. This could entail adding WPT components to already- existing parking spaces or planning new parking buildings with WPT systems built right in.

Another alternative is to create WPTsystems, such as portable or modular WPT systems, that are simple to install and remove from parking spaces. When necessary, these devices may be transferred between parking spaces. They can also be employed in places where permanent installation is neither possible nor desirable. The proposed idea's block diagram is shown in Fig-1.

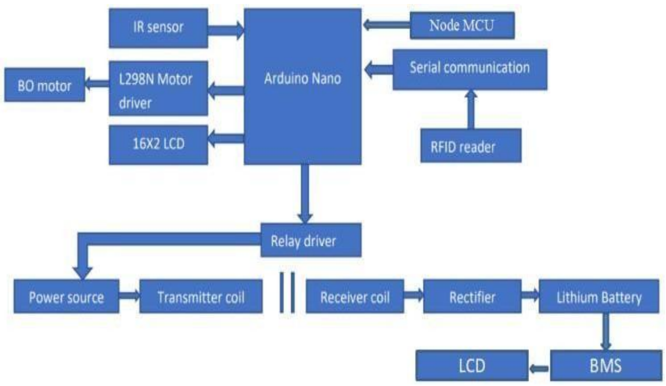


Fig-1: Block diagram

STEP 1: An IR sensor and servo motor are connected to an Arduino Nano in order to detect acar and open gates for parking. The available slotsare shown on an LCD.

STEP 2: An android application can be used to control the electric automobile, allowing for precise parking.

STEP 3: The battery level will be shown so that the user can choose whether to charge the vehicle or simply park.

STEP 4:

CASE 1: CHARGING: Charging pad is installed on the ground at a parking spot and the receiving pad is installed on the underside of the vehicle. The two pads communicate wirelessly to transfer power to the battery. RFID is used to detect the amount based on the charging units and parking charges.

CASE 2: PARKING: The user only need to park the vehicle. So the RFID detects the amount for parking.

8. WORKING

Initially once the electric car enters the parking area, the IR sensors detect the slot vacancy. Then the RFID tag is read and card balance is displayed. If the driver has sufficient balance he/she can enter the slot. Depending upon the driver's choice, separate cards are given for parking and charging respectively.

Once the car has been parked properly in the slot, the charging of the battery takes place. The frequency should be high for efficient transfer of power from primary to secondary coil. Thus, the low frequency AC current supplied by the grid is converted into DC.

Then AC/DC converters convert it to high frequency current. The transmitter coil receives this high frequency AC, which subsequently produces an alternating magnetic field that cuts the reception coil and results in the output of AC power in the receiver coil. After being rectified and converted to DC, the voltage that was induced on the secondary side is subsequently delivered to the battery via the Battery Management System (BMS).Compensation networks are implemented on both sides to preserve the resonant frequencies.

Once the car enters the slot, the time count starts. During exit the RFID card is read and charge is deduced from the card depending upon the time duration, the car has been parked/charged in the slot.

Finally the data about the history of all the cars parked/charged in the slots is displayed in a web page application. We have interfaced Node MCU with Arduino Nano to send the corresponding datato the webpage.

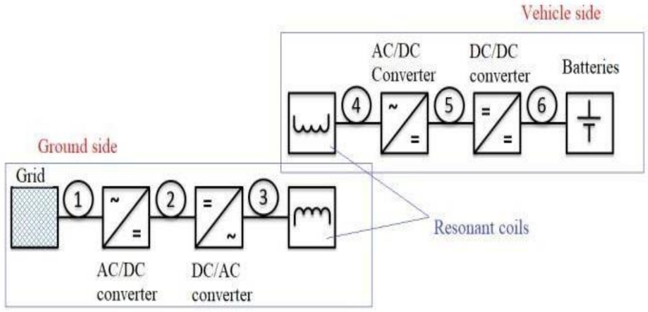


Fig-2: Components of WPT system

9. CONTROL OF WIRELESS CHARGING SYSTEM

9.1 EFFICIENCY OF WPT

WPT's maximum efficiency is attained as a result of three different types of factors: The first group takes care of the load change. In order to achieve the best impedance, impedance matching techniques are used. Inductors and capacitors are passive elements used in passive impedance matching, whereas DC-DC converters are used in active impedance matching to match the load. The second group focuses on output control, which includes frequency control and load variation. The third category is devoted to controlling input power. Reactive power input is kept to a minimum to boost system effectiveness. The output voltage needs to stay constant. WPT systems can accomplish this by using numerous pads on the primary side. The two-step tracking method is what this is known as. We can change the direction and ratio of the current in the primary coil on the transmitting side may both be changed for best system efficiency.

9.2 SYSTEM MISALIGNMENT

The coefficient of coupling between the transmitter and receiver coils determines how well power is transferred. Increased lateral misalignment results in a reduction in mutual inductance. The efficiency of the charging mechanism suffers as a result, decreasing the transmitted power. There has been some research on vehicle lateral misalignment, and a few methods to boost system effectiveness have been put forth. These methods use two- dimensional coil position, various pad structures, three coil detection systems, and adaptive impedance matching circuits. The efficiency of the system can also be increased by frequency regulation.

9.3 LOSSES

In power electronics, loss analysis is crucial to evaluating the system's performance and optimizing its design characteristics. The growing use of power electronics in various applications underscores the importance of high-accuracy power loss measurement. For measuring total system loss, it is important to understand the losses of each component of the system, particularly the converter's conduction and switching losses.

Resonant switching can be achieved by switching the inverter at the resonance frequency. This technique also allows for high-frequency operation compared to hard-switching PWM converters.

The converter's conduction losses are dependent on the type of switches used, with SiCMOSFETs being a common type. The conduction losses are affected by the current flowing through the switch and the on- state drain-to-source resistance. Understanding these loss mechanisms is critical for optimizing the design and improving the efficiency of power electronics systems.

10. OUTPUT AND RESULTS

The project demonstrates that wireless power transmission for electric vehicles using inductive coupling, RFID tags, and intelligent parking stations is a promising technology that can offer a practical, secure, and effective method of charging electric vehicles.

Wireless charging is made possible by the use of inductive coupling, which eliminates the need for physical cords or connectors and lessens the strain on the charging port on the car. While smart parking stations equipped with sensors and communication technologies enable real- time monitoring and control of the charging process, RFID technology is used to identify and track electric vehicles as they approach and leave the charging station. In order to optimize the effectiveness of the charging process and regulate the charging current and voltage to ensure safe and effective charging of the electric vehicle battery, power electronics are used in the charging station to control the flow of energy between the transmitter coil and the receiver coil.

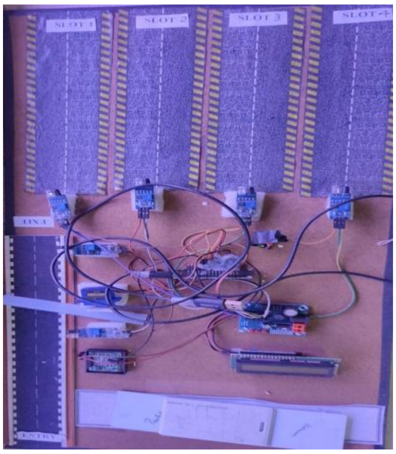


Fig-3: Smart parking

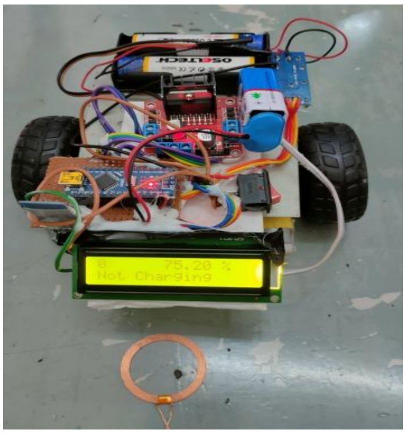
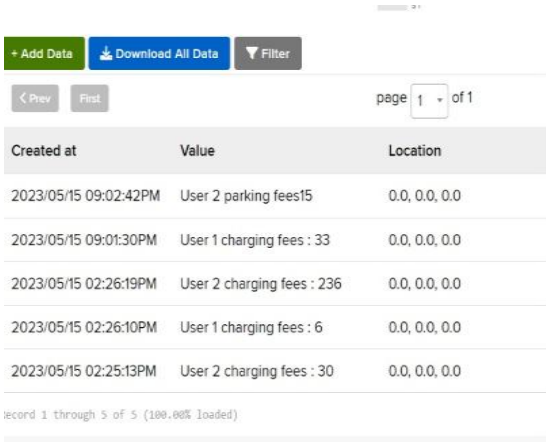


Fig-4: Initial state of Battery before Charging

Fig-5: Charging of Battery using Magnetic coil



Created at	Value	Location
2023/05/15 09:02:42PM	User 2 parking fees15	0.0, 0.0, 0.0
2023/05/15 09:01:30PM	User 1 charging fees : 33	0.0, 0.0, 0.0
2023/05/15 02:26:19PM	User 2 charging fees : 236	0.0, 0.0, 0.0
2023/05/15 02:26:10PM	User 1 charging fees : 6	0.0, 0.0, 0.0
2023/05/15 02:25:13PM	User 2 charging fees : 30	0.0, 0.0, 0.0

Fig-6: Cloud Server Data

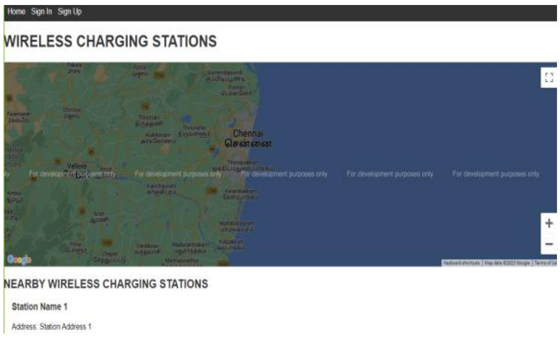


Fig-7: Website for identifying the charging stations

11. INVOLVEMENT OF INDUSTRIES

Numerous industry and government entities are actively involved in the development of Wireless Power Transfer (WPT) technology. Notable WPT suppliers include Qualcomm, Evatran, WiTricity, SEW, LG, Samsung, Momentum Dynamics, and HaloIPT. Additionally, infrastructure companies such as NRG Energy, Better Place, and Southern California Edison are participating in the initiative. Several prominent Auto OEMs, including

BMW, Mitsubishi, Audi, Daimler, Ford, GM, Honda, Chrysler, Nissan, Phoenix, and Toyota, are also contributing to the efforts. Furthermore, bus manufacturers Proterra and Volvo are part of the collaborative endeavor. Tier 1 suppliers such as Delphi, Magna, Maxwell, and Panasonic are actively engaged in the project. Lastly, government and research organizations are key participants.

12. DISCUSSION AND FUTURE RESEARCH

The cultural acceptance of EVs has grown, and more people are currently driving them than ever before thanks to the development and growth of the supporting technology. For EVs to maintain a practical driving range, there must be enough batteries for energy storage. When compared to conventional cable charging, EV wireless charging is a significant enabling technology that offers many advantages. It makes it possible to charge EVs without the usage of connectors. The wireless charging method decreases the size of the battery, lowers the starting cost, saves time, and increases the driving distance. . However, there are still a lot of areas where wireless charging solutions can be improved, which is now achievable thanks to technical advancement. But the increased operating frequency causes the inverter's switching losses to increase. Additionally, using semiconductor devices at high frequencies may cause them to reach high temperatures, necessitating the need for a cooling system. Therefore, a trade-off between charging speed and coil size is necessary for optimal coil design. The coil design also affects other factors including energy efficiency, leakage flux, power density, and tolerance to misalignment in addition to quick charging capability. Therefore, it is advised that additional research be done in the area of the best coupler design to fulfill the goals.

The primary and the secondary side coils must be exactly aligned to produce a WPT that is very effective. Flux leakage caused by the misalignment lowers the effectiveness of the system. A metal object nearby may become linked because of the flux leakage, which could harm the object in addition to causing energy loss. Misalignment is a significant issue that needs to be resolved in wireless charging systems. To increase the tolerance for misalignment, various strategies have been suggested. These suggested techniques employ various coil geometries combined into a single unit, overlapping arrangement, and resonance frequency tuning circuits. These techniques could add to the weight and demand more room. The misalignment issue is being addressed using alternative techniques that do not rely on changing the coil geometry. After that, the receiver coil and transmitter are aligned using an autonomous control system. Electromagnetic meta material can also be used to correct the misalignment.

An open space exists between the wireless charging system and the electric vehicle (EV) when it is utilized to charge the latter. While the EV is being charged, a foreign object could fall within this open space. If the object is made of metal, the strong magnetic field will cause eddy currents to flow, which will heat it up. As a result, the charging mechanism may operate differently than usual and result in a safety incident. A wireless charging system should employ metal object detection (MOD) and foreign object detection (FOD) which comprises and living object detection (LOD). The three different types of detection system works based on the principle - system parameter-based detection, wave- based detection and field-based detection methods.

The common consensus is that EVs with DWCS need small-sized batteries. Both the cost and the weight of the EVs are decreased as a result. The best battery and wireless charging system size has been evaluated by some research. Another issue that needs to be resolved is interoperability between various charging system types and EVs. Both sides' compensation networks should have compatible shapes, sizes, and other parameters.

13. CONCLUSION

We have reviewed charging of electric vehicles using wireless power transmission. Due to its user-friendliness and environmental friendliness, wireless charging is seen as being superior to conventional cable charging solutions. Additionally, it does away with the need for cables and mechanical connectors, avoiding the inconveniences and risks that come with them. In general, either microwave, laser, or mutual coupling are used for wireless power transmission. However, only mutual coupling-based techniques are frequently used in wireless charging. The mutual coupling-based inductive and capacitive power transfer techniques are employed for contactless power transfer and charging of electric devices. It is determined that inductive power transmission offers advantages and is the best approach for wirelessly charging electric vehicles after a discussion, comparison, and contrast of the two techniques. Also reviewed and presented are crucial components of a wireless charging system, including the charging pad, compensation topologies, system misalignment, communication, and control. A brief summary of battery kinds and models is also provided because the batteries affect a number of charging system factors.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to Sri Venkateswara College of Engineering for providing me with the resources and support necessary to complete this project. I am also extremely grateful to my mentors, **Dr. S. Muthukumar** (Head of Department - ECE), **Mrs. K S Subhashini**, for their invaluable guidance, feedback, and encouragement throughout this process. Their expertise and insight were instrumental in shaping the direction of this project and refining its execution. Thank you for sharing your time, knowledge, and expertise with me. Your contributions have been immeasurable and will always be remembered.

REFERENCES

[1]. A. M. Ahmed and O. O. Khalifa , " Wireless power transfer for electric vehicle charging Conference Paper " , AIP conference, doi:10.1063/5.0032383, December 2020.

[2]. D. Ashok, A. Tiwari and V. Jirge, "Smart Parking System using IoT Technology," 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE), Vellore, India, 2020, pp. 1-7, doi: 10.1109/ic- ETITE47903.2020.457.

[3]. R. Kavin, V. K. Gowri, M. Naveenaa, T. Navishree and J. Nithish, "Wireless Power Transmission in Electric Vehicle Using Solar Energy," 2021 3rd International Conference on Signal Processing and Communication (ICPSC), Coimbatore, India, 2021, pp. 78-80, doi: 10.1109/ICSPC51351.2021.9451697.

[4]. Y. Agarwal, P. Ratnani, U. Shah and P. Jain, "IoT based Smart Parking System," 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS), India, 2021, pp.464-470,doi:10.1109/ICICCS51141.2021.9432196.

[5]. M. Zamani, M. Nagrial, J. Rizk and A. Hellany, "A review of inductive power transfer for electric vehicles," 2019 International Conference on Electrical Engineering Research & Practice (ICEERP), Sydney, NSW, Australia, 2019, pp. 1-5, doi: 10.1109/ICEERP49088.2019.8956971.

[6]. M. Zucca, P. Squillari and U. Pogliano, "A measurement system for the characterization of wireless charging stations for electric vehicles," 2020 Conference on Precision Electromagnetic Measurements (CPEM), Denver, CO, USA, 2020, pp. 1-2, doi: 10.1109/CPEM49742.2020.9191828.

[7]. J. Qu, L. He, N. Tang and C. -K. Lee, "Wireless Power Transfer Using Domino-Resonator for 110-kV Power Grid Online Monitoring Equipment," in IEEE Transactions on Power Electronics, vol. 35, no. 11, pp. 11380-11390, Nov. 2020, doi: 10.1109/TPEL.2020.2989757.

[8]. H. Feng, R. Tavakoli, O. C. Onar and Z. Pantic, "Advances in High-Power Wireless Charging Systems: Overview and Design Considerations," in IEEE Transactions on Transportation Electrification, vol. 6, no. 3, pp. 886-919, Sept. 2020, doi: 10.1109/TTE.2020.3012543.

[9]. X. Mou, R. Zhao and D. T. Gladwin, "Vehicle-to-Vehicle charging system fundamental and design comparison," 2019 IEEE International Conference on Industrial Technology (ICIT), Melbourne, VIC, Australia, 2019, pp. 1628-1633, doi: 10.1109/ICIT.2019.8755057.

[10]. D. Patil, M. K. McDonough, J. M. Miller, B. Fahimi and P. T. Balsara, "Wireless Power Transfer for Vehicular Applications: Overview and Challenges," in IEEE Transactions on Transportation Electrification, vol. 4, no. 1, pp. 3-37, March 2018, doi: 10.1109/TTE.2017.2780627.