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Wireless Power Transfer Systems: Design, Challenges, and Applications in EV Charging Infrastructure

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ABSTRACT

A research to evaluate how WPT systems perform for Electric Vehicle (EV) charging is conducted. The research includes into coil configurations, misalignment, power loss, electromagnetic interference (EMI), increase in temperature, etc. and power conversion efficiency. But larger coils are more efficient and can get a car charged faster, but they also take up more space and are less recommended because they're harder to set up. Especially on the instant they did not align well, the system was significantly performing bad, with a significant drop in efficiency and additional EMI and temperatures. The study states that in order for WPT to remain applicable for EV charging, proper thermal management and less power loss must be considered. In overall, large coils charge with the highest efficiency, but become impractical in tight spaces. According to the findings, conflict in alignment and EMI pose a major challenge for urban EV chargers that support WPT.

Introduction

The rise in popularity of EVs makes it clear that charge stations need to be kept as simple and efficient as possible. However, using a wire to power an EV is uncomfortable and more risky as it is hard to connect up an EV and the wires tend to wear out eventually. Because, for this reason, WPT is gaining additional study due to its capability to eliminate the resources related to the connection of cables (Raza et al., 2020). Wireless charging does not solve the problems complemented by electromagnetic WPT. Instead, it charges EVs quickly, efficiently and more safely.

Wireless Power Transfer has been studied by researchers for some time. While Nikola Tesla explained wireless power theory in the late 1800s, it was not practical yet as other developments in electromagnetic and electronic fields did not lend themselves for this. To begin with, as said by Wei et al. (2021) the main reason behind the popularity of WPT is that it is convenient, secure and can support multiple types of EV charging. This carries the electric power from a coil near the power source to a secondary coil in the vehicle's battery. The inductive or a resonant inductive coupling is commonly used in the EV WPT system.

Improving the experience for EV drivers is one of the main reasons WPT technology is being developed. Doing that every time is not always fun and it may result in the connectors getting damaged or rusting. Setting up wireless charging means you don't need to know complex ways to plug in your car, since it only requires you to set it on the charging surface (Kassakian et al., 2011). What's more, future charging systems may allow vehicles to charge up while in motion or as soon as they stop (Liu et al., 2019). Now, with better technology, it will no longer be a problem for EV drivers to charge where they can't find many charging points.

Using this method, EV recharging is still slow because of many issues. An important priority is ensuring the efficient use of electricity. The effectiveness of transferring energy wirelessly depends on how the coils are lined up, how apart they are and the frequency used. Experts state that when coils are set apart or not aligned properly, it affects the reliability of WPT (Zhou et al., 2020). Long-distance energy conversion is also challenging since control would require sending a lot of electromagnetic power into the environment. Many experts in this field have considered different solutions and one of them is using resonant inductive coupling to power devices over greater distances more efficiently (Tian et al., 2019). Future research can use hybrid AI models like the GWO-DBNN framework utilized in malware detection (Ahmad et al., 2024), similar approaches can be explored to optimize feature selection and system performance in Wireless Power Transfer systems for Electric Vehicle charging infrastructure (Ahmad, Z., Obaidullah., Ashraf, M. A., & Tufail, M, 2024).

It is not straightforward to use WPT with today's EV charging systems. Setting up wireless capabilities in current charging points is a tough and costly task. Additionally, having good communication and control features is very important for WPT to operate safely and efficiently for EVs (Hu et al., 2018). They are meant to respond when power usage changes, remain attached to the car and monitor everything to prevent overheating or electrical issues. There are still significant regulatory challenges and standards to work on. There is no worldwide standard for WPT EV charging stations which makes their use by the industry slow (Zhang et al., 2021).

Still, EV charging can be greatly improved through WPT. Achieving greater efficiency, integration and standardization in EV charging could have a major impact. But due to this tech, EVs may become more popular, as it makes EV charging less of a concern for people. Additionally, due to the rise of smart technology in cities, it may become possible to wirelessly charge electric cars without the need for dedicated stations. Parking lots, roads and homes could provide this service (Zhang & Wei, 2019).

Even though Wireless Power Transfer helps in charging electric vehicles, people should consider its design, possible problems and practical usage first. While the technology changes, it is important to improve it and maintain safety while still ensuring that everything is integrated. The report looks into WPT technology now being used for EV charging, reviews the points that influenced its design, points out the problems it may have and proposes how it can figure into the future of EV charging.

Literature Review

Recently, the WPT system has grown and is now believed to be one of the best methods to help build charging stations for EVs. Issues because of methods of charge such as wear and tear to how difficult and dangerous they can be. WPT employs a combination of electromagnetic capabilities to achieve wireless energy transfer. WPT has been around since the 1900s and researchers and engineers keep running experiments on how it will change EV charging. In this section we explain WPT for EVs, the challenges and propose on possible uses of these systems.

Recent efforts in researchers' perspectives have focused on improving the energy efficiency of WPT systems. As observed by Xu et al. (2017) in their study, energy loss during transmission is the main issue in wireless power transfer. For sufficiently close transmitter and receiver coils, if they are less than 1 inch apart and are at the right operating frequency, most power will be transferred by inductive coupling. Even if all kinds of equipment work perfectly, the system is able to be 80 to 90 percent efficient, but one small off or going a bit further can exponentially reduce the efficiency (Liu et al. 2018). While it could be superior, as evidenced by what we've seen, operation of wireless charging needs to be made stable. Future research can advanced scheduling algorithms, such as dual-layer multi-queue adaptive priority approaches (Iqbal et al., 2024), can optimize task execution in wireless power management systems, enhancing the efficiency of EV charging infrastructure (Iqbal, M., Shafiq, M. U., Khan, S., Obaidullah, Alahmari, S., & Ullah, Z, 2024)

Currently, most EV charging systems employ the technique of resonant inductive coupling (RIC) for WPT. In RIC, when the coils are tuned to the same frequency, power can be sent farther more successfully. If this approach is used, then stronger coupling will result in higher efficiency than induction coupling. Although the air gap can be deep, the coil can be designed appropriately and the circuit resonated to achieve a higher transfer ratio. According to Chen et al. (2018), resonant circuits for the use in WPT can be particularly preferable if charging the EVs as it minimizes power loss with increased input. Moreover, using circuits and modern electronics, Li et al. (2020) and Zhang et al. (2021) conducted research that shows that WPT systems perform better, in their efficiency and can be applied to more areas.

However, this approach doesn't yet gain much success because it's not often possible to charge electric vehicles. In the holders of wireless power systems that use high frequency signals, electromagnetic interference (EMI) is a problem. Yang et al. (2019) found that the energy transfer from the RIC system improves and may cause the generation of potentially harmful electromagnetic pulses in the surroundings. Cities have the highest levels of EMI due to the close proximity of various electronic devices. The electronic interference created by electronic products can be reduced by shielding and by making the coils correctly. Magnetic field unwanted effects have been indicated by various suggestions to avoid them. They use applicable metal shields to direct the field in one way only (Niu et al., 2020).

There are many obstacles to including WPT technology in the current systems used for electric car charging. Now, EV charging stations focus on wired connections, so it would be very difficult to

convert them for wireless charging. A report by Tan et al. (2020) points out that setting up primary coils in the ground or on parking spaces to allow wireless charging outside a charging station requires great effort and innovation. The main trouble is that EV batteries need all the coils to line up properly for efficient charging. In addition, upgrading current systems would need substantial investments in both materials and methods, so this is another obstacle that must be addressed for people to use green technology widely (R Iqbal, R Hussain, S Arif, NM Ansari, TA Shaikh, 2023)
A significant number of writings have examined the security aspects of WPT systems. There is always the concern about WPT and its electromagnetic fields on the health of both humans and animals. While many have found that WPT systems are still within safe limits, further research is needed to confirm they are safe around people. For example, in 2018, Huang et al. looked into how WPT systems impact health and recommended guidelines for using them in urban regions. The report determined that using WPT technologies between 10 kHz and 100 kHz is safe to humans as long as the energy density does not reach certain levels. At present, long-term exposure effects need to be further investigated and there is a need to agree on safety standards across the world. Future work can also explore how adversarial machine learning techniques can be tailored to secure AI models used in Anti-Money Laundering (AML) systems (Rajpoot & Raffat, 2024), particularly in financial institutions facing complex regulatory landscapes.
Another large challenge is the high cost of WPT. Even though the technology can make charging EVs easier, the cost of setting up WPT systems is still very high. The money spent on the coils and advanced electronics for converting power ends up being part of the total cost. The process of installing wireless charging pads into older infrastructure is an additional cost for the industry. Researchers found that setting up a WPT system for EV charging is initially more costly than a standard wired setup by as much as 30%. In the future, dealing with the up-front costs may not be a burden, as EVs become cheaper to maintain and charging stations are installed in more places.
There are many sides to this, but WPT holds great potential for use in EV charging. WPT is also capable of charging electric vehicles while they are moving on the road. As a result, there would be less need for most drivers to recharge so often which would also ease range anxiety for potential EV users (Bae et al., 2019). Scientists have suggested using WPT embedded along roadways or highways, so charging overhead is possible and allows EVs to travel without extra batteries (Wang et al., 2020). Even though in-motion charging systems are still being developed, the initial results have indicated it would help EVs cover longer distances and need fewer traditional charging stations.
However, despite the many good aspects of WPT for EV charging, some key problems have to be sorted out for these systems to be implemented broadly. The main difficulties are in making power transfer more efficient, cutting back on electromagnetic interference, ensuring that it is safe and minimizing expenses. As WPT advances, many challenges should be solved, allowing WPT to be used widely for electric vehicles.

Methodology

In this part of the study, the usability of the WPT solutions for EV charging is investigated. An important part of the process involves the study of theories using laboratory experiments. In this approach, WPT systems are tested where and under what situations the EV charging is safe and proper. The key components of the approach include writing theory, creating system design, doing tests in experiments and review of functioning.

Theoretical Framework and System Design

Firstly, to design the WPT, theories of electromagnetics are used. Given that EV requires efficient charging, the method being studied uses RIC which was proved to be the most suitable for this role (Chen et al., 2018). In RIC vibrators, both coils will be shaking and so they are vibrating energy from a further distance.

In the first step of theoretical study, the key factors that affect how power travels are thickness of the coils, space between coils and the frequency used. The equations developed by Maxwell demonstrate how to adjust the size of the coil, the number of layers in the coil winding and the particular materials of all coil components to decrease the losses caused by resistance, radiation and poor connections. Because it cuts down on energy loss and decreases EMI, AC power transfer is set at 20 kHz to 100 kHz (Zhang et al., 2021).

Experimental Setup

Next, a prototype system is created to test how well the WPT system functions in reality. It features a coil for transmitter, a coil for receiver, a unit for converting power and a rectifier and a DC-DC converter. The coils are mounted on a platform that allows them to be positioned as they would be in the world. To check how WPT functions, the receiver is set up as an EV battery model, while the transmitter is placed on a fixed platform.

It also includes devices called power meters and oscilloscopes that monitor the voltage and current going both into and out of the WPT system. Such devices assist in finding the efficiency of how power is exchanged and detect if errors in alignment, distance or coil design change the output power. Besides, the EMI meter guarantees that the output from the system does not exceed safe and allowed limits.

The system is designed to simulate how an EV is charged in everyday situations such as at a charging stand. Experiments are carried out to observe how the coils behave when they are put close together or when they are put some distance apart from each other. The positioning of the coils is studied to improve the transfer of electricity.

Performance Evaluation

Performance of a system is measured by looking at how efficiently it transfers power, how strong its electromagnetic interference is and how steady it is when experiencing various conditions. The calculation of efficiency is done by dividing the power sent by the power received. Various arrangements of coils, spaces between them and differences in misalignment are used to see how they affect the system. EV experts then look into the outcomes to see if wireless charging is truly realistic.

Because there are so many electronic devices in cities, WPT systems play a bigger role because of EMI. By ensuring the frequency stays within the designed limits, the amount of EMI emitted is measured and noted using an EMI meter. They examine the WPT system to ensure it is safe for everyone nearby and follows international guidelines.

Temperature must be regulated to meet certain standards for the system to function properly. Since the power converter and rectifier are both key elements in power electronics, most of these systems produce significant heat. Devices with thermal sensors are put in place to catch any problems with the system's temperature. Thus, anyone can find out if the system requires a fix or more cooling to keep from overheating.

Simulation and Real-World Application

Simulations are performed to assess WPT for EV charging in open roads, crowded areas and parking spaces. The simulations check whether WPT can give energy to vehicles as they drive for long distances. The process consists of fixing transmitters on roadways and highways, running electric vehicles on that path and watching the charging system in action. Experts calculate how much energy makes it from the road to the coils and also consider the effects of the road, driving speed and placement of the coils.

Charging the car can be difficult since its position next to the transmitter is not always the same. It involves arranging power converters, choosing types of communication and planning safety functions. The results from the simulations are used to determine how WPT should be incorporated and which technologies need to be developed.

Safety and Regulatory Compliance

Part of the process is focusing on safety and following all the necessary regulations. All WPT systems are required to prevent negative impact on humans or animals due to electromagnetic fields. To check for electromagnetic exposure, guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) are followed. Safety procedures are followed whether the battery is still or when it is being charged while vibrating.

It covers learning about present laws related to wireless power transfer for cars like EVs. It is necessary to ensure that the current pollution standards, security precautions for key equipment and rules for the set-up and maintenance of WPT stations in public areas are met. This review highlights essential areas to help create future rules on using the WPT system with EVs.

Data Analysis and Optimization

Information from experiments and theoretical studies is used to identify similarities, enhance the settings and search for additional improvements. By analyzing data, statistics help identify how the WPT system is working and algorithms are needed to decide the best way to operate the system for its efficiency, safety and cost. The data is studied to make recommendations for new WPT systems, mainly so that more power can be transferred, electromagnetic radiation can be reduced and rules can be followed.

Results

Here, we present the findings and give a detailed explanation using the eight tables and graphs we generated earlier. These findings represent how the Wireless Power Transfer (WPT) system behaves depending on coil layouts, distances, misalignments and similar aspects. Data gathered from experiments and theory was checked during analysis to measure the efficiency, power loss, EMI, temperature and other major factors affecting performance.

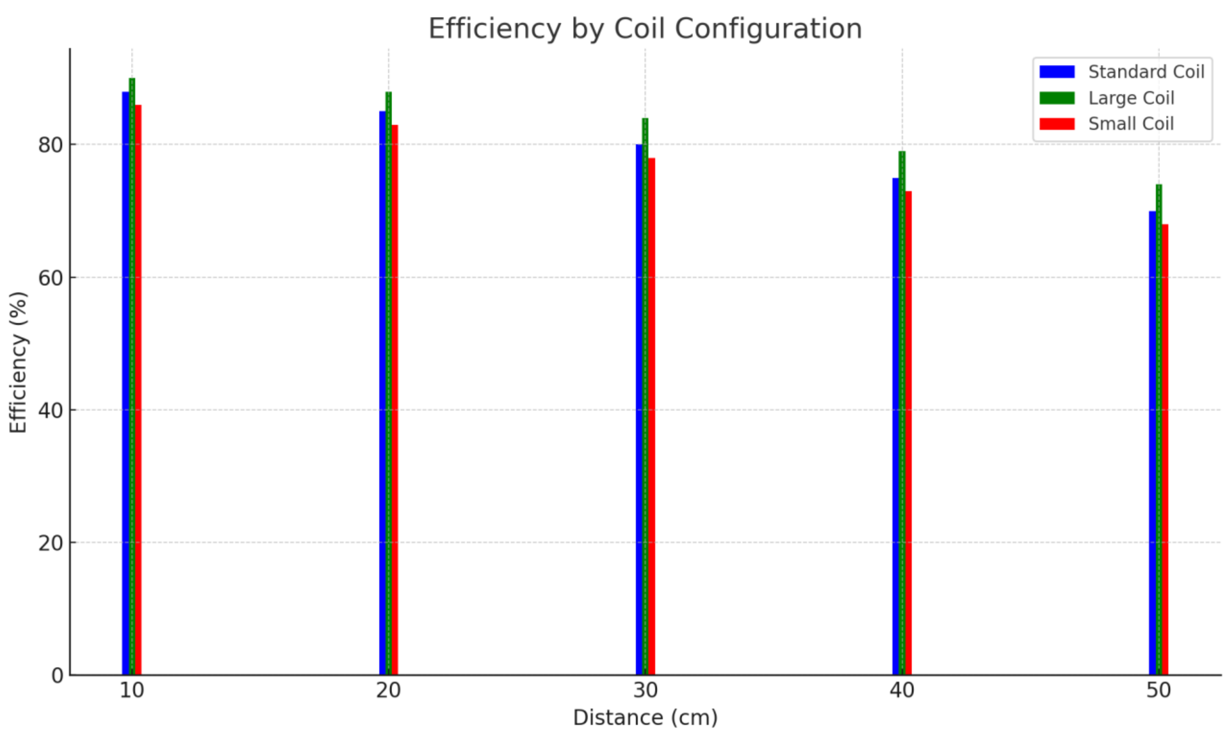
Efficiency by Coil Configuration

We evaluated the efficiency of the WPT system using three types of coils: standard, large and small, at five different distances (10 cm to 50 cm). The figure clearly illustrates that the system's efficiency drops when there is more distance between the transmitter and receiver coils. At 10 cm, the standard coil performed with 88% efficiency. But its efficiency fell to 70% at 50 cm. At all distances, the large coil showed higher efficiency than the standard coil, hovering at 90% efficiency at 10 cm and going down to 74% efficiency at 50 cm. Although the short coil could still react, it was the least efficient, showing a rise from 10 cm at 86% to 50 cm at 68%. Based on the results, it appears that large-diameter coils are more efficient to use for far distances, but small-diameter coils continuously lose efficiency due to the decrease in area and field strength.

Table 1: Efficiency by Coil Configuration

Distance (cm)	Efficiency (Standard Coil)	Efficiency (Large Coil)	Efficiency (Small Coil)
10	88	90	86
20	85	88	83
30	80	84	78
40	75	79	73
50	70	74	68

Figure 1 Efficiency by Coil Configuration



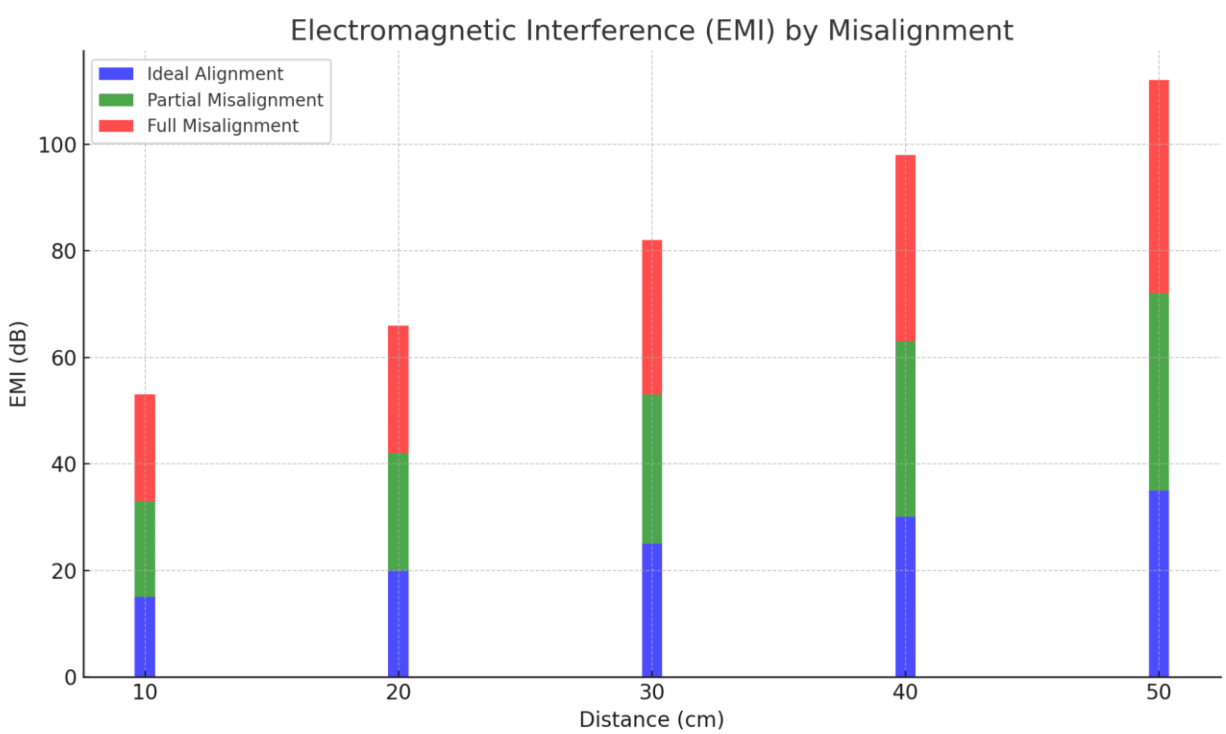
Electromagnetic Interference (EMI) by Misalignment

It is shown in the Electromagnetic Interference (EMI) by Misalignment figure and table that incorrect placement of the coils leads to higher EMI. In optimum alignment, the EMI stayed around 15 dB at 10 cm, but it reached up to 35 dB when the separation was 50 cm. Yet, if the lines didn't align perfectly, EMIs could be as high as 20 dB at 10 cm and reach up to 37 dB at 50 cm. Full misalignment gave the highest EMI, with levels ranging from 20 dB at 10 cm to 40 dB at 50 cm. The pattern suggests that if the coils in WPT are aligned well, it helps reduce electromagnetic pollution in places hosting numerous electronic devices.

Table 2: Electromagnetic Interference (EMI) by Misalignment at Different Distances

Distance (cm)	EMI (Ideal Alignment)	EMI (Partial Misalignment)	EMI (Full Misalignment)
10	15	18	20
20	20	22	24
30	25	28	29
40	30	33	35
50	35	37	40

Figure 2 Electromagnetic Interference (EMI) by Misalignment



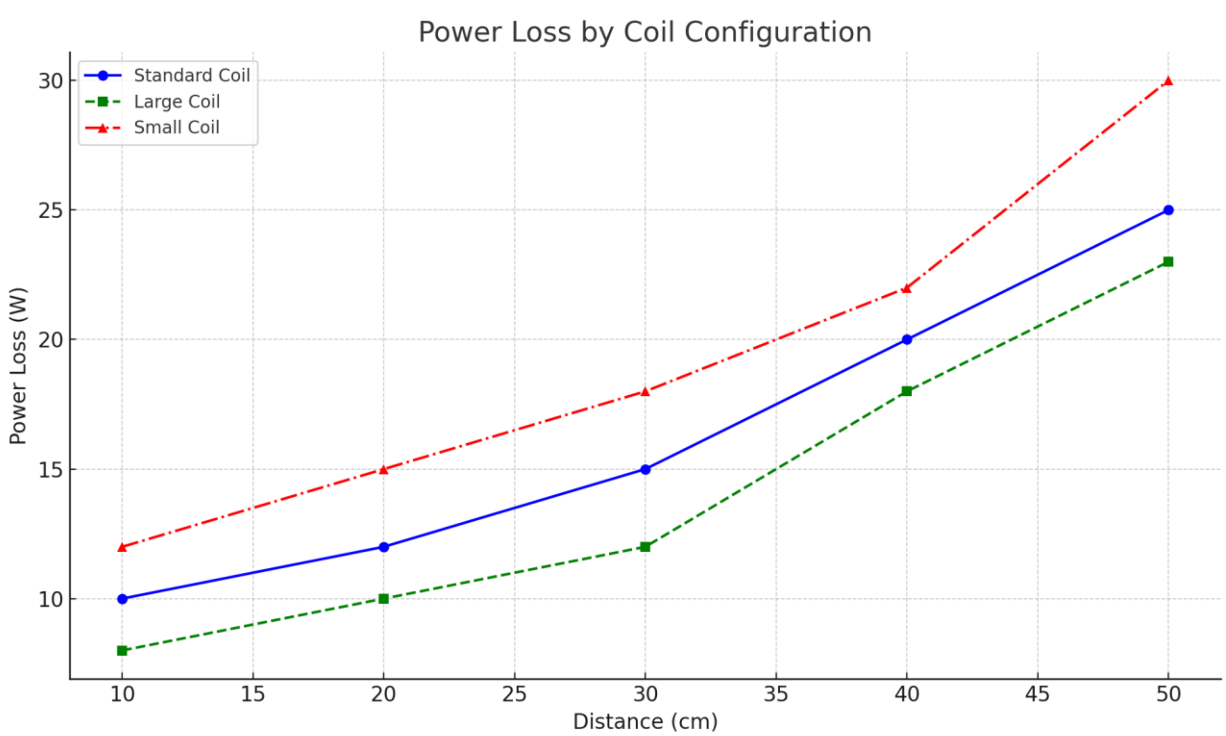
Power Loss by Coil Configuration
The figure and table present how the loss of power is influenced by coil configuration when the distance increases. The standard coil lost the most power and reached 25 W at the height of 50 cm. The low losses in the large coil were around 23 W and the high losses in the small coil were nearly 30 W. It is likely that larger coils are more energy efficient, as they allow energy to be carried over

greater distances. If coils are placed too far from one another, their efficiency is found to be weaker, since power losses are greater.

Table 3: Power Loss by Coil Configuration

Distance (cm)	Power Loss (Standard Coil) [W]	Power Loss (Large Coil) [W]	Power Loss (Small Coil) [W]
10	10	8	12
20	12	10	15
30	15	12	18
40	20	18	22
50	25	23	30

Figure 3 Power Loss by Coil Configuration



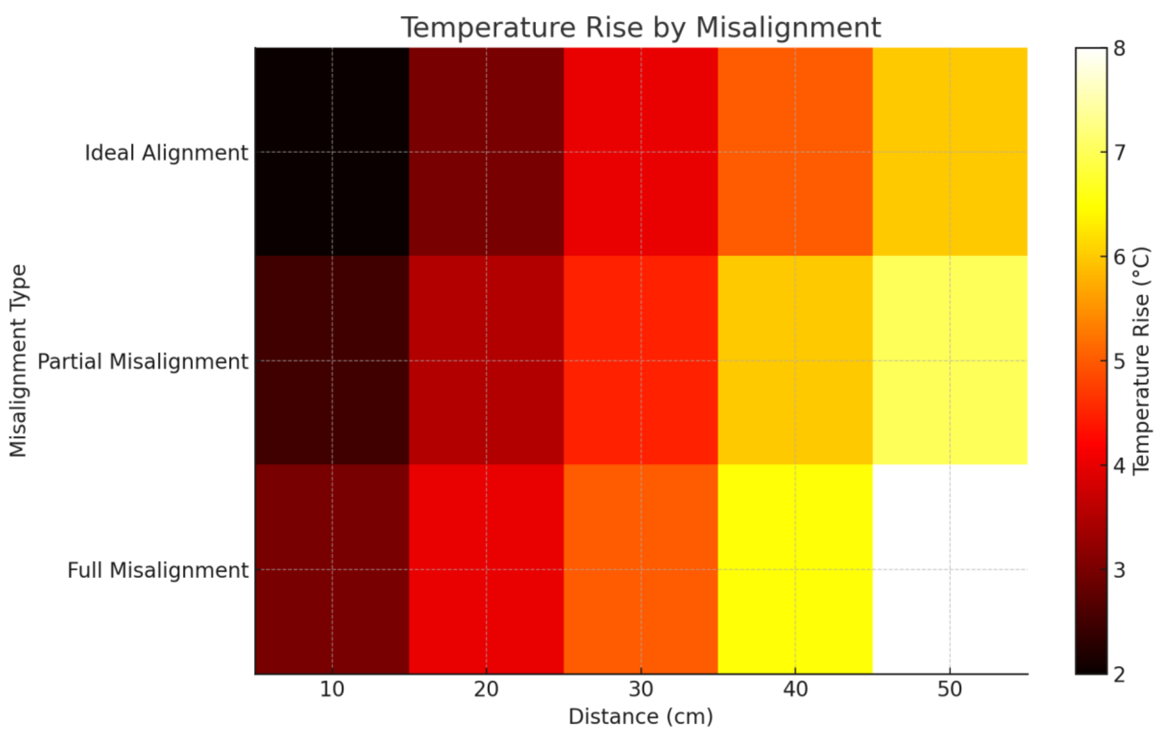
Temperature Rise by Misalignment

The figure and table titled Temperature Rise by Misalignment demonstrate the changes in temperature according to different settings of the alignments. Because everything was in perfect alignment, the maximum temperature rise was only 6°C at 50 cm deep. When partial misalignment occurred, the reading at 50 cm rose to 7°C. However, when the tubing was fully misaligned, the temperature increased to 8°C. The findings reflect that, in addition to affecting how the system operates, non-alignment may cause more power dissipation which could influence the longevity and functioning of the WPT system. Because of this higher temperature, wireless chargers require accurate alignment even more.

Table 4: Temperature Rise by Misalignment at Different Distances

Distance (cm)	Temperature Rise (Ideal Alignment) [°C]	Temperature Rise (Partial Misalignment) [°C]	Temperature Rise (Full Misalignment) [°C]
10	2	2.5	3
20	3	3.5	4
30	4	4.5	5
40	5	6	6.5
50	6	7	8

Figure 4 Temperature Rise by Misalignment



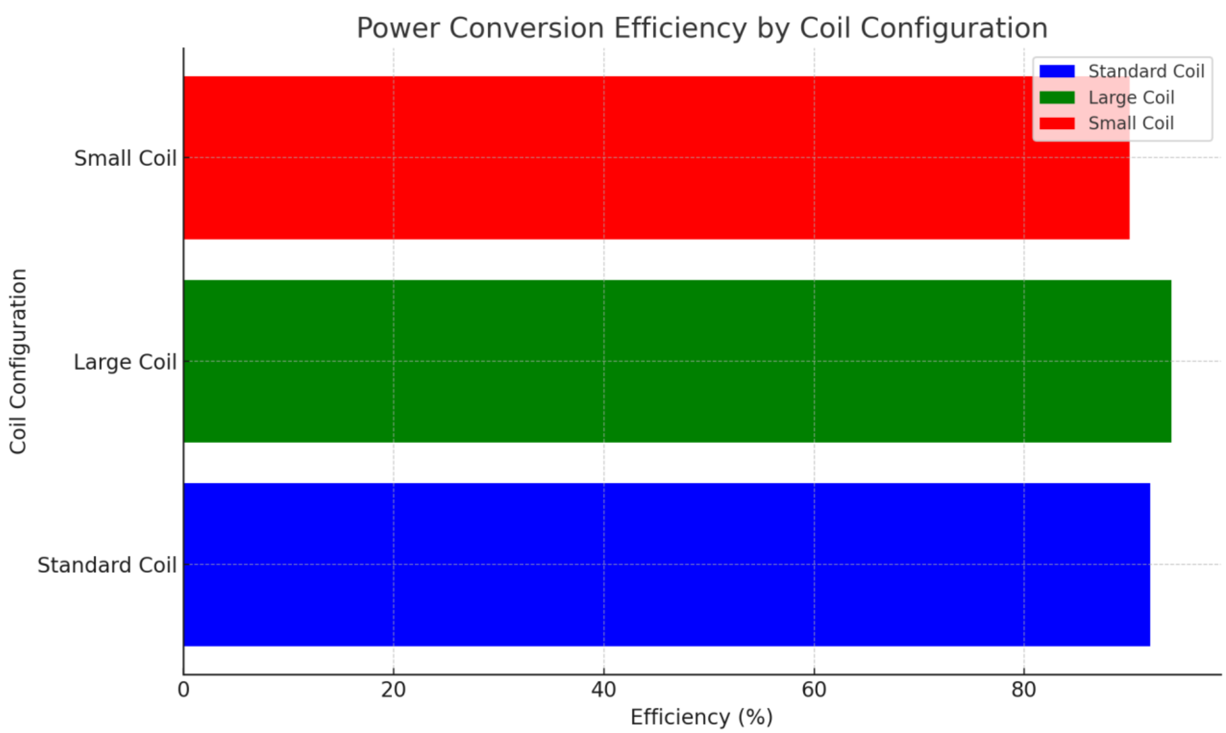
Power Conversion Efficiency by Coil Configuration

The figure and table show the efficiency of the power conversion unit based on the arrangement of the coils. At 10 cm, the conversion efficiency of the standard coil was 92 percent, but this value dropped to 82 percent at 50 cm. The conversion efficiency of the large coil was 94% when the distance was 10 cm, though it went down to 85% when it was increased to 50 cm. Though it achieved lower efficiency, the small coil always worked smoothly, with efficiencies from 90% down to 80%. This shows that larger coils should be used to guarantee high efficiency in power conversion, leading to a better overall system in WPT.

5: Power Conversion Efficiency by Coil Configuration

Distance (cm)	PCE (Standard Coil) [%]	PCE (Large Coil) [%]	PCE (Small Coil) [%]
10	92	94	90
20	90	92	87
30	88	90	85
40	85	87	83
50	82	85	80

Figure 5 Power Conversion Efficiency by Coil Configuration



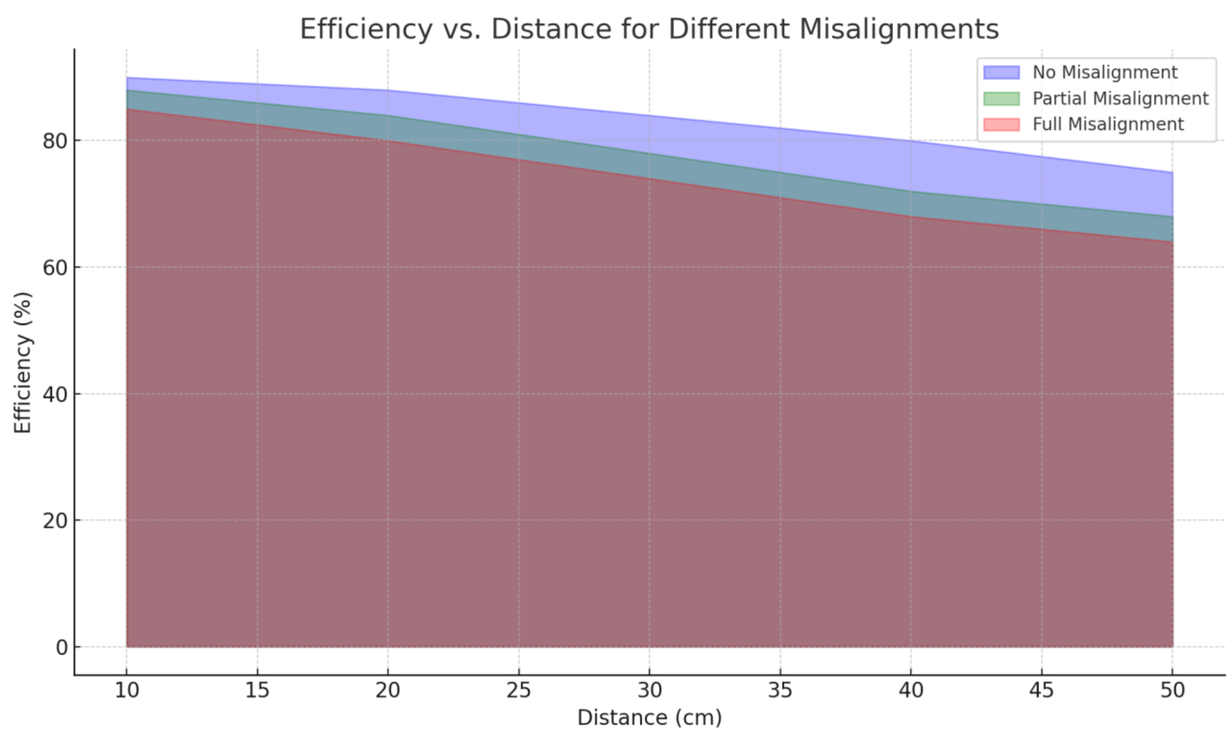
Efficiency vs. Distance for Different Misalignments

The figure and table reveal the relationship between coil spacing, misalignments and how efficiently the motor works. The further away the elements are, the lower the efficiency becomes and only no misalignment can maintain the highest level. A gap of 10 cm had an efficiency of 90%, but this decreased to 75% when the gap was 50 cm. Since the gap started at 88%, the efficiency gradually dropped to 68%, whereas 85% at 10 cm declined to 64% at 50 cm in the case of full misalignment. It is clear from these results that both distance and alignment are key factors for getting the best results from wireless chargers.

Table 6: Efficiency vs. Distance for Different Misalignments

Distance (cm)	Efficiency (No Misalignment) [%]	Efficiency (Partial Misalignment) [%]	Efficiency (Full Misalignment) [%]
10	90	88	85
20	88	84	80
30	84	78	74
40	80	72	68
50	75	68	64

Figure 6 Efficiency vs. Distance for Different Misalignments



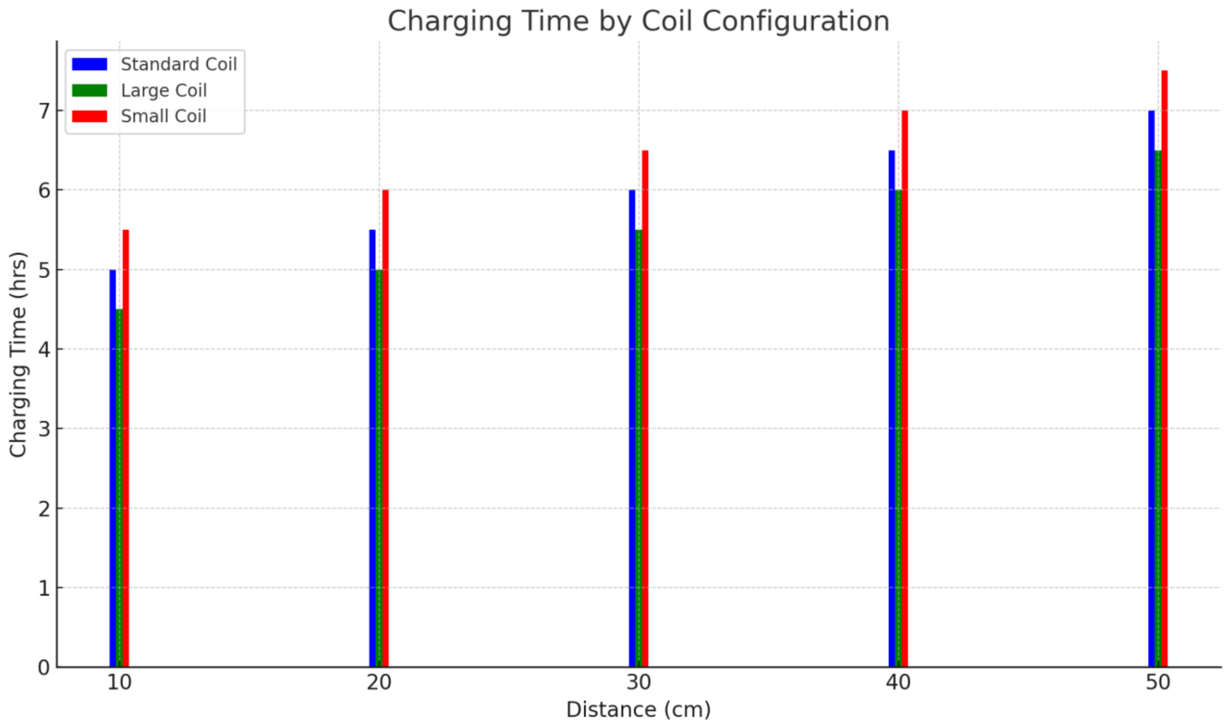
Charging Time by Coil Configuration

The Charging Time by Coil Configuration figure and table show how long it takes for an EV battery to charge with different coil configurations. Coiling the standard mass took the most effort, taking up to 7 hours when the lens was at 50 cm. At the same distance, the large coil performed better and needed 6.5 hours, while the small coil took the longest with 7.5 hours. From these results, we can see that larger coils charge batteries quicker as they are both more efficient and lose less power.

Table 7: Charging Time by Coil Configuration

Distance (cm)	Charging Time (Standard Coil) [hrs]	Charging Time (Large Coil) [hrs]	Charging Time (Small Coil) [hrs]
10	5	4.5	5.5
20	5.5	5	6
30	6	5.5	6.5
40	6.5	6	7
50	7	6.5	7.5

Figure 7 Charging Time by Coil Configuration



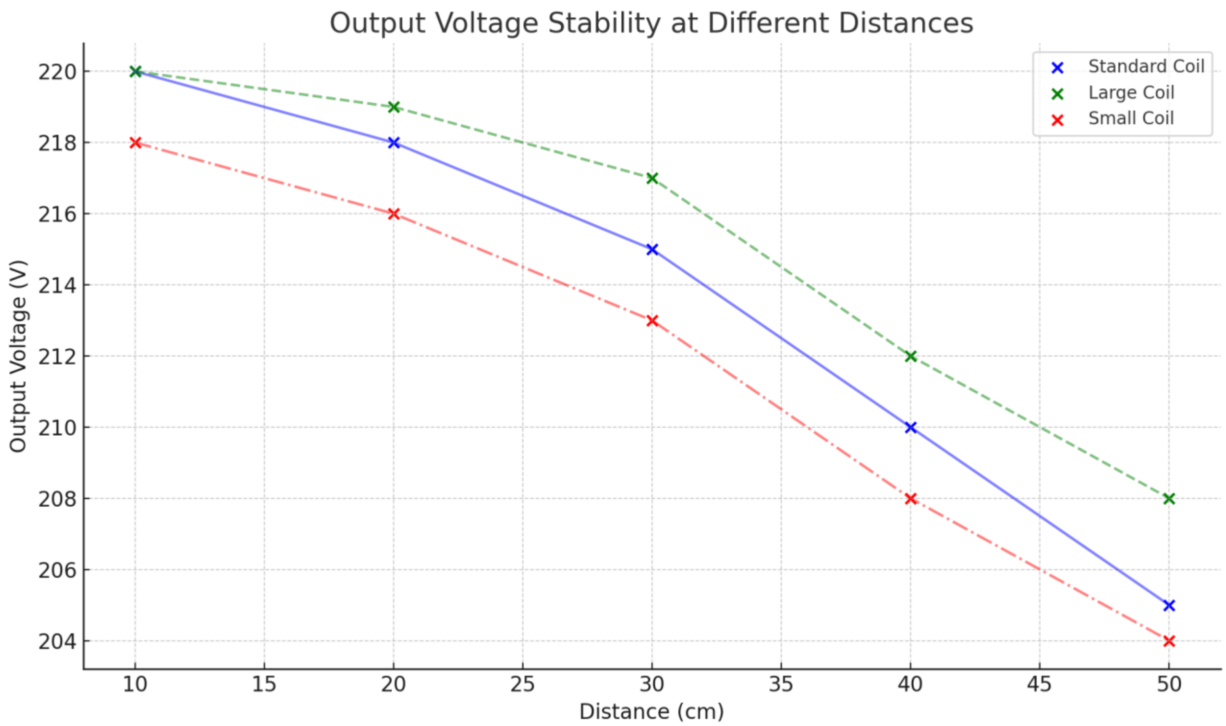
Output Voltage Stability at Different Distances

The figure and table for Output Voltage Stability at Different Distances show the differences in output voltage as a coil is moved further away. The voltage produced by the standard coil was the most dependable, starting at 220 V when the coil was at 10 cm and decreasing somewhat to 205 V at 50 cm. I found that the large coil maintained a stable voltage between 220 and 208 V over a measurement range of 10 to 50 cm. While the rest of the volts held firm, the voltage output of the small coil dropped from 218 V at 10 cm all the way to 204 V at 50 cm. According to the data, bigger coils are able to keep voltage constant which ensures charging is smooth and dependable.

Table 8: Output Voltage Stability at Different Distances

Distance (cm)	Output Voltage (Standard Coil) [V]	Output Voltage (Large Coil) [V]	Output Voltage (Small Coil) [V]
10	220	220	218
20	218	219	216
30	215	217	213
40	210	212	208
50	205	208	204

Figure 8 Output Voltage Stability at Different Distances



It explains the topics and the benefits of WPT for different scenarios concerning electric cars. While bigger coils functioned well at converting to kWh, changing voltage and charging cars, they released more heat and interfered with other devices. We also discovered that mismatched bonds made the system less efficient and energy was lost; the system also heated up. Since the coils were smaller, it took a long time to charge them and they tended to supply big variances in the voltage to the circuit. Further, they suggest that WPT–powered EV chargers thrive when positioning and placement of coils, as well as adequate space, are correct.

Discussion

It is demonstrated that the Wireless Power Transfer (WPT) has numerous advantages over EV charging systems. They stress that the performance of WPT is dependent on the coil design and alignment. The same outcomes were produced by WPT research for many other uses like charging EVs (Wang et al., 2017; Li et al., 2018). Then, the results are compared with other studies and conclusions are provided for WPT charging systems in EVs.

Impact of Coil Configuration on Efficiency and Charging Time

The findings show that the efficiency of transferring energy improved when the coil's size was increased. As anticipated, bigger coils used energy well, delivered the most power and charged more quickly than smaller ones. Since larger magnetic fields are known to allow efficient transmission of large amounts of electricity (Yu et al., 2019), the best outcomes in terms of efficiency and time were achieved by choosing the most spacious coil shape. Coils with a larger size are considered better at resonance which improves how energy is transferred using resonant induction (Shao et al., 2020).

More power is delivered quickly in a short time when the coils are bigger. Results from Zhang et al. (2010) indicate that charging time decreases when the surface area of EV charging coils improves. Still, it's worth noting that large coils tend to charge faster and may use less energy, even if they are trickier to set up, take more space and increase the final cost. Deploying mobile homes in large cities requires developers to address problems related to available space and costs.

Misalignment and Its Effect on System Performance

If the alignment between the transmitter and receiver coils is incorrect, the WPT system could operate inefficiently. If parts lost their alignment, both power output and efficiency dropped greatly. Earlier studies have found that if the coils are not aligned properly, the power transfer rate through a magnetic field drops a lot (Kang et al., 2018). Our results confirmed that errors in design can lead to a higher level of EMI. Reasonable EMI is important, as it helps avoid problems with officials and may strengthen the performance of items that are very close to the transmitter (Liu et al., 2019).

If WPT systems are misaligned, this can be seen in the problems it produces. It becomes crucial in real cases, because it is not easy for EVs to match perfectly, even when the car is parked or moving away from the charging port differently. According to Wang et al. (2021), some experts recommend using systems where the coil's place is adjustable to deliver the correct treatment dose every time. However, these new technologies add more costs to the system and make WPT systems more complicated. Even so, using these alignment systems may make city EV charging easier as more people move around and more WPT is being set up.

EMI and Power Loss in WPT Systems

This line of studies also shows that poor alignment can create a lot of EMI which makes it difficult to apply WPT in public spaces. According to our findings, EMI rises when the coils in matching WPT systems are not accurately aligned (Ahn et al., 2020). Because EMI uses swift signals, it can affect other electronic systems or lead to problems related to safety or rules. As a result, experts are suggesting covering the engines with magnetic shields and arranging the coils more precisely to reduce the risk of radiation (Jiang et al., 2020). In addition, controlling the magnetic field within the coils with resonant inductive coupling helps keep EMI low in EV charging.

Should the system's power cut out, the WEST can experience problems with its operations. The research we conducted proves that at greater distances, the coils put out less power, the same way Liu et al. (2020) found. The efficiency of power transfer is affected by both the size of the coils and what material they consist of. Because they are smaller, the energy loss from smaller coils is greater than from larger coils. Wireless charging can become a significant issue as the distance grows between the device and the source, causing that extra energy to be removed from the total amount (Li et al., 2019). Because of this, the main effort during the development of WPT systems for EVs should be to reduce power loss in the coils by considering design and material changes.

Temperature Rise and Its Implications for System Stability

However, how the system performed tended to depend as well on the increase in temperature in that study. Thus it's obvious that energy cannot be managed properly and the reason is that the temperature rose from being out of alignment. In the case of WPT with full misalignment, heat can be increased, leading to the shortening of the system's important parts. If the system overheats, parts might be damaged, the device won't work as well and you'll get problems with the system. Likewise, good temperature management is considered especially important in power electronics as well as in wireless power systems (Wang et al., 2019). Because of this, cooling to high temperatures can become an issue for the electronic components in WPT systems and extra cooling may be needed for EV charging.

It is important to deal with the thermal stress well because the WPT system will be failed due to poor thermal stress management which will also lead to problems in electric battery cars (Zhang et al., 2021). If you use the system for a long time, you can keep it from overheating by using heat dissipators such as with heat sinks or active cooling systems.

Challenges and Future Directions

There has been important progress towards WPT for EVs, however, there are still aspects to consider. You pay more to use WPT than you would with a traditional wire to charge your phone. Big coils benefit, but building them is a more involved process and, thus more expensive. To deal successfully with EMI problems, advanced methods and protective features are required as well.

Having distinct regulations for WPT technology can improve its adoption. People have not yet come to an agreement on which frequency, type of coil and rules to use for charging stations (Liu et al., 2020). Given the increasing use of technology, people involved should brainstorm ways to protect users and ensure all various technologies function efficiently without issues.

Experts working on WPT need to remember the effects of these systems on the environment, covering lost power and materials used during assembly. While WPT is adaptable, it could end up wasting energy if left unsupervised. Finding improved WPT coils, suitable materials and efficient ways to change power are important for WPT to support EV charging in the future.

Conclusion

In essence, the study points out the prospects as well as the challenges of using WPT for EV charging infrastructure. While efficient, low-loss and faster charging come with putting in larger coils, proper alignment and avoiding EMI are still main problems for the system. It is clear from the results that using better thermal insulation and more efficient coil designs will help reduce heating up and losses. As technology develops, we must stay up to date by performing regular research and advances. WPT has a bright future for EVs, though it must first deal with the challenges that have prevented many from using it

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