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Paper Title:

Camera-Based Misalignment Detection and Hardware Validation for EV Wireless Charging Systems

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OUTLINE

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- Conclusions
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INTRODUCTION

Why Wireless EV Charging is Important:

- **Enhances safety by reducing the risk of electric shocks** and wear and tear from plug-in chargers.
- **Eliminates the need for cables,** making charging more convenient and user-friendly.
- **Enables fully automated charging,** allowing EVs to charge without manual intervention.

Challenges in Regular Wireless EV Charging:

- **Misalignment between coils reduces efficiency**, leading to energy loss and longer charging times.
- **Limited flexibility in parking position**, as precise coil alignment is required for effective charging.
- **Power transfer is affected by environmental factors**, such as temperature, interference, and foreign objects.

Problem Statement:

- Misalignment in wireless EV charging reduces power transfer efficiency, causing energy loss and longer charging times.
- Weak magnetic coupling due to misalignment leads to inefficient energy transfer.
- Current solutions rely on manual adjustments, which are slow, inconsistent, and not practical for large-scale use.
- Lack of automated realignment prevents real-time correction, making wireless charging unreliable.
- Solving this issue will improve efficiency, reduce energy waste, and enhance the user experience in wireless EV charging.

PROBLEM STATMENT/ RESEARCH QUESTIONS/OBJECTIVES

Research Questions:

- How does misalignment impact power transfer efficiency?
  It weakens magnetic coupling, causing energy losses and slower charging.

- Can OpenCV detect misalignment accurately in real time?
  Yes, it analyzes images to track coil positions and identify deviations.

- What are the key challenges in implementing an automated misalignment correction system?
  Challenges include sensor accuracy, processing speed, and environmental factors.

- How does automated misalignment correction contribute to sustainable transportation?
  It improves efficiency, reduces energy waste, and supports EV adoption.

PROBLEM STATMENT/ RESEARCH QUESTIONS/OBJECTIVES

Objectives:

- This work aims to develop an AI/ML-driven system utilising OpenCV to detect and correct misalignment in wireless EV charging. Misalignment between transmitter and receiver coils reduces power transfer efficiency, leading to energy losses and longer charging times.

- The system will use real-time image processing and sensor data to make precise adjustments.

- Experimental validation will be conducted to measure efficiency improvements and verify system reliability under real-world conditions. This innovation aims to make wireless EV charging more efficient, automated, and practical.

LITERATURE SURVEY

Design and implementation of a high misalignment-tolerance wireless charger for an electric vehicle with control of the constant current/voltage charging (2024) :

- The goal of this work is to develop a wireless charging system for electric vehicles (EVs) that can still work efficiently even if the charging coils are not perfectly aligned.

- It focuses on handling both sideways (lateral) and tilted (angular) misalignment between the charger and the vehicle. The system will include an automatic alignment mechanism to improve charging efficiency.

- This research will help future wireless charging designs by showing how important it is to correct misalignment automatically.

LITERATURE SURVEY

A comprehensive review on charger technologies, types, and charging stations models for electric vehicles (2024) :

- Review different EV charging technologies, including wired and wireless charging. Analyze charging station designs, focusing on architecture, battery storage, and renewable energy integration.

- Explore V2G (vehicle-to-grid) and V2V (vehicle-to-vehicle) technologies for better energy management and grid support. Examine on-board and off-board charging topologies used in EVs.

- Investigate the use of machine learning to improve power conversion efficiency with advanced switching techniques.

LITERATURE SURVEY

Modeling and implementation of a machine learning-based wireless charging system with high misalignment tolerance (2024) :

- This study develops a machine learning-based wireless charging system for EVs that remains efficient even when the charging coils are misaligned.
- It tests eight different scenarios to analyse how misalignment affects power transfer and mutual inductance. The system achieves high misalignment tolerance, allowing charging to work even with significant position shifts.
- It improves power transmission efficiency by up to 68.7% in some cases and ensures stable power delivery, transferring between 968W and 1006W, even in misaligned conditions.

LITERATURE SURVEY

Electric vehicles: Battery technologies, charging standards, AI communications, challenges, and future directions (2024) :

•Explore different EV battery technologies, including lithium-ion, lead-acid, nickel-based, and solid-state batteries. Compare battery types based on energy density, lifespan, charging time, cost, and environmental impact.

•Highlight lithium-ion batteries as the most common and efficient choice for modern EVs. Discuss the strengths of lithium-ion batteries, such as high energy density, long lifespan, and fast charging.

•Address the weaknesses of lithium-ion batteries, including their sensitivity to temperature.

CE2CT

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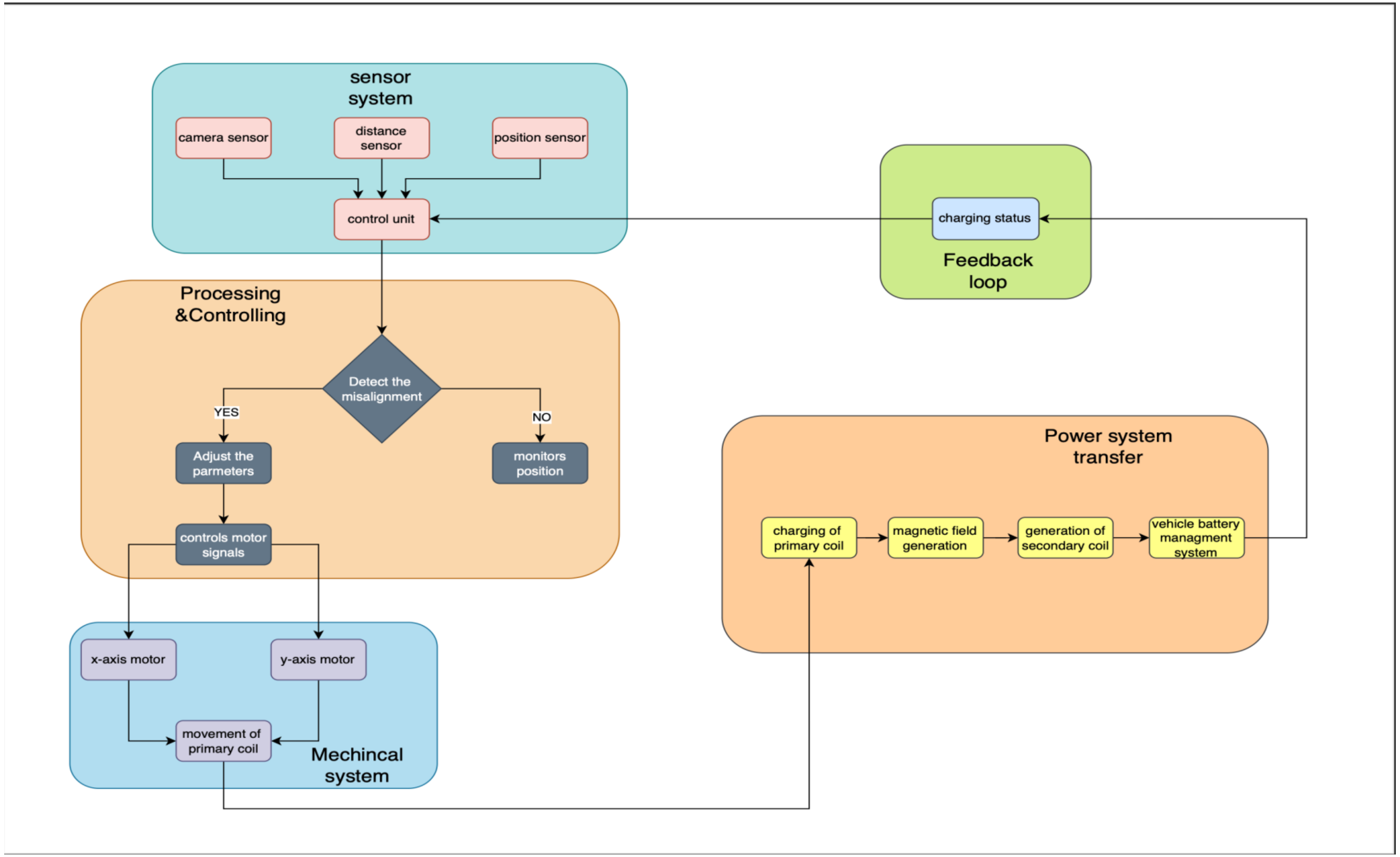
FLOW DIAGRAM



METHODOLOGY

Real-Time Coil Alignment Using Camera-Based Tracking:

- The system uses the camera's center as the **P coil center**, making it the fixed reference point for alignment.
- The **S coil center** is identified as the center of an oncoming circle detected in the camera’s view. By continuously tracking the positional relationship between these two centers, the system detects misalignment in real time.
- If the S coil is off-center, adjustments are made to align it with the P coil. This dynamic tracking ensures precise coil alignment, improving power transfer efficiency in wireless EV charging.

METHODOLOGY

- The work entails an initial prototype for distance-dependent performance measurements of wireless power transfer between primary (transmitter) coils and secondary (receiver) coils.

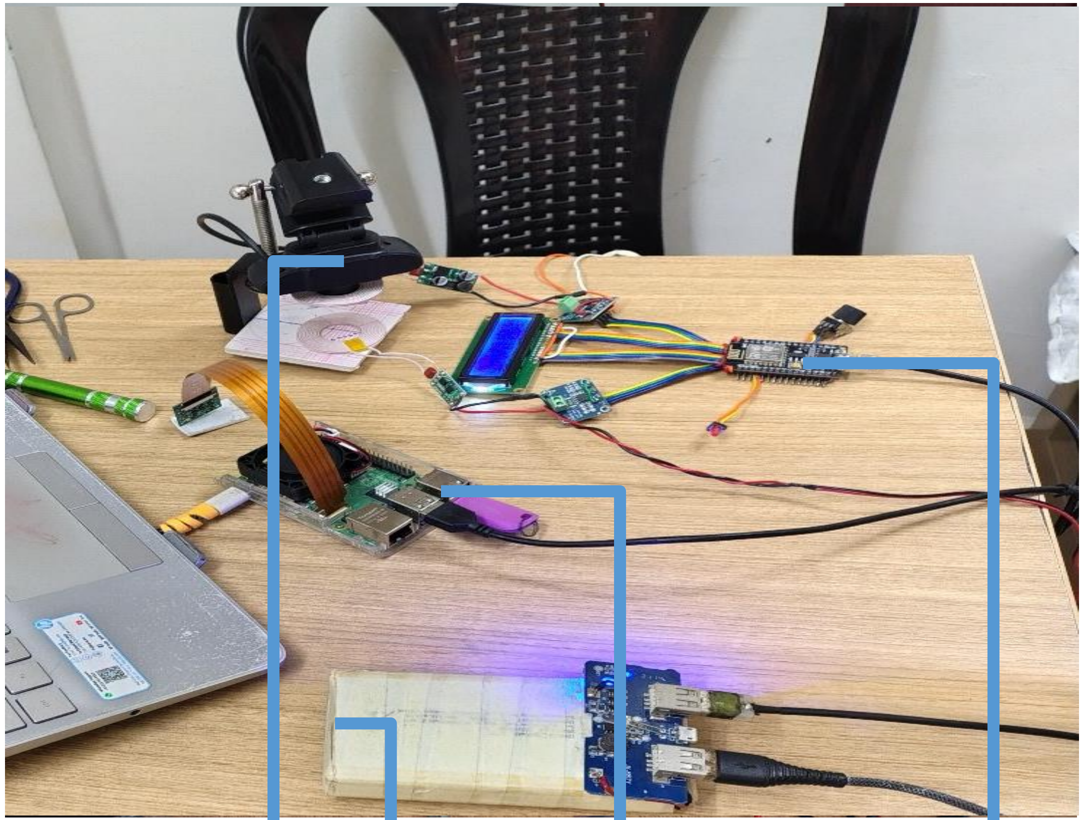
- Measurements are made with systematic variation of the vertical distance (D) between the coils at every discrete interval of 0 mm, 3 mm, 6 mm, 7 mm, and 10 mm and Above 10.

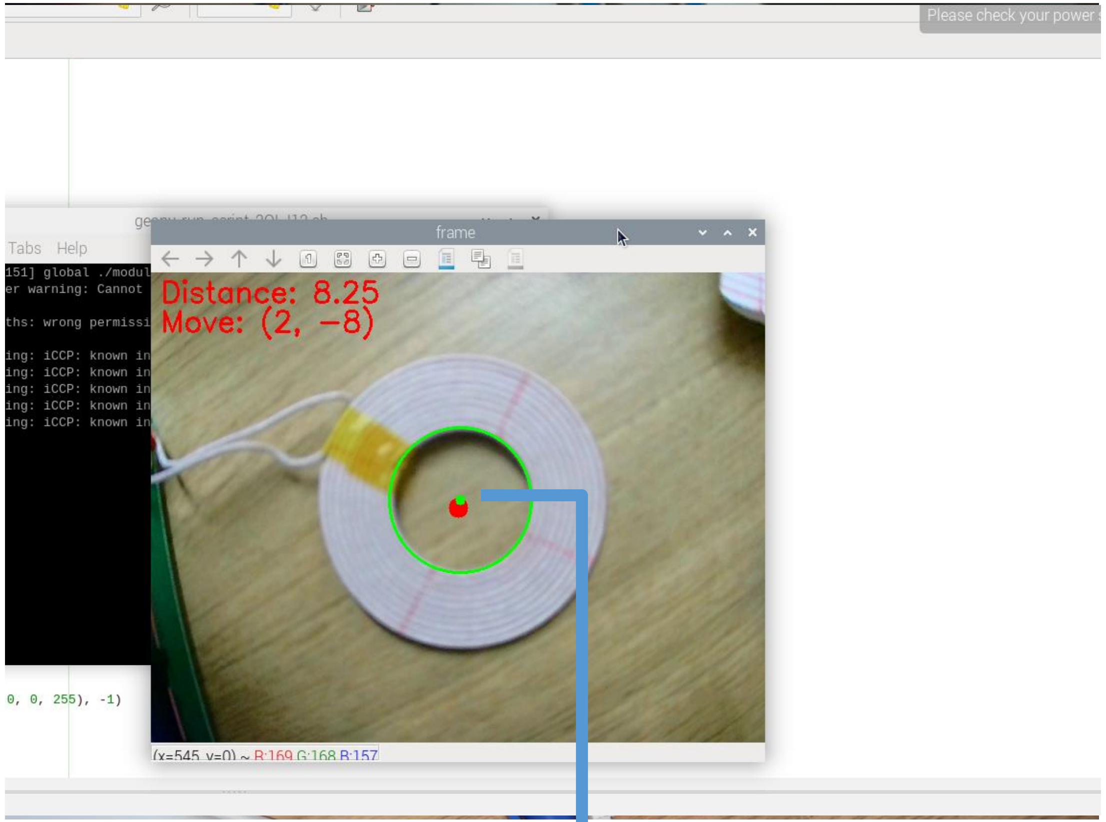
- All the following parameters at each distance are recorded:

  - Distance(D) [mm];
  - Transmitter Coil Voltage(V);
  - Transmitter Coil Current(mA);
  - Transmitter Coil Power(mW);
  - Receiver Coil Voltage(V);
  - Receiver Coil Current(mA);
  - Receiver Coil Power(mW).

METHODOLOGY

Implementation of Hardware and Software:





Camera and wireless coil setup

Power supply

Raspberry 5 for OpenCV

Power monitoring system

Coil alignment detection

METHODOLOGY

Hardware implementation: AT H=0mm

$H = 0\,\mathrm{mm}$

Distance (D) [mm]	Transmitter Coil Voltage (V)	Transmitter Coil Current (mA)	Transmitter Coil Power (mW)	Receiver Coil Voltage (V)	Receiver Coil Current (mA)	Receiver Coil Power (mW)
0	4.96	343	1704.88	4.36	158	688.88
1.41	4.93	342	1687.26	4.44	164	728.16
2.82	4.95	318	1578.10	4.26	133	566.58
4.24	4.92	401	1975.92	5.09	122	621.98
5.65	4.87	467	2277.49	5.08	143	726.44
6.40	4.90	412	2018.80	3.78	119	450.42
7.07	4.98	268	1330.64	1.03	53	54.59
8.48	5.02	194	974.88	0	0	0

METHODOLOGY

Hardware implementation: AT H=3mm, 6mm

$H = 3\,\text{mm}$

Distance (D) [mm]	Transmitter Coil Voltage (V)	Transmitter Coil Current (mA)	Transmitter Coil Power (mW)	Receiver Coil Voltage (V)	Receiver Coil Current (mA)	Receiver Coil Power (mW)
0	4.92	398	1953.36	5.08	170	863.60
1.41	4.92	395	1946.40	5.09	172	875.48
2.82	4.91	397	1946.07	5.09	144	733.44
4.24	4.88	446	2172.08	5.08	157	797.96
5.65	4.91	398	1957.08	3.87	107	413.49
7.07	4.96	281	1395.36	2.05	96	196.80
8.48	5.02	178	892.36	0	0	0

$H = 6\,\text{mm}$

Distance (D) [mm]	Transmitter Coil Voltage (V)	Transmitter Coil Current (mA)	Transmitter Coil Power (mW)	Receiver Coil Voltage (V)	Receiver Coil Current (mA)	Receiver Coil Power (mW)
0	4.88	457	2223.76	4.94	148	731.12
1.41	4.90	424	2076.60	4.07	120	488.40
2.82	4.93	366	1802.38	3.44	88	302.72
4.24	4.96	306	1514.56	2.50	127	317.50
5.65	5.01	205	1025.05	0	0	0

METHODOLOGY

Hardware implementation: AT H= 7mm, 10mm

$H = 7\,\mathrm{mm}$

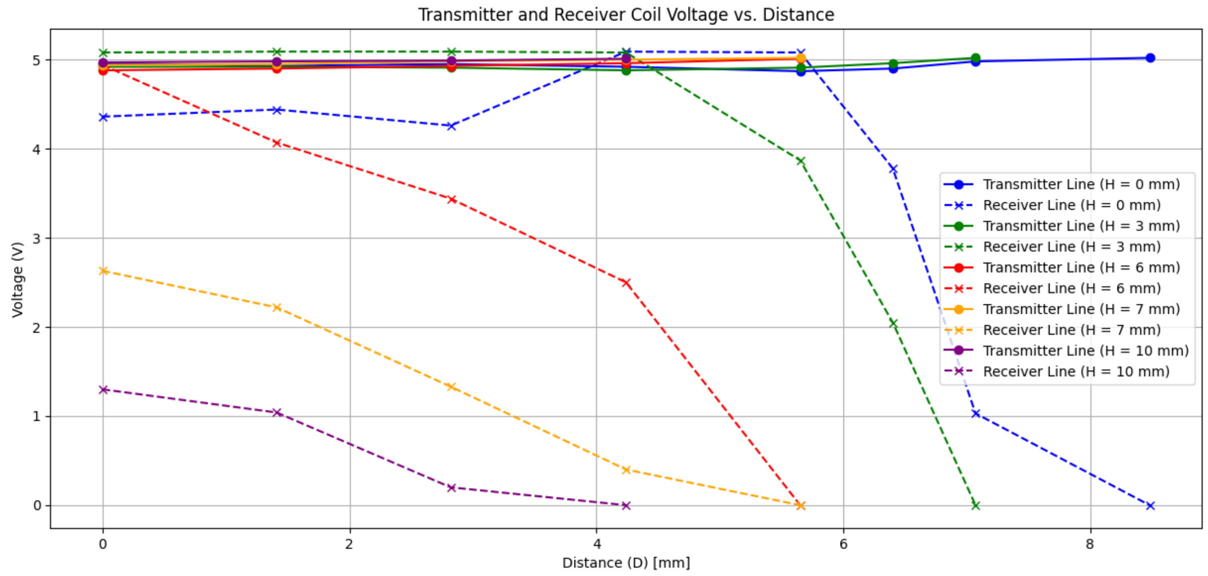
Distance (D) [mm]	Transmitter Coil Voltage (V)	Transmitter Coil Current (mA)	Transmitter Coil Power (mW)	Receiver Coil Voltage (V)	Receiver Coil Current (mA)	Receiver Coil Power (mW)
0	4.94	335	1653.90	2.63	117	308.91
1.41	4.95	315	1554.25	2.22	102	226.44
2.82	4.98	267	1332.66	1.33	68	90.44
4.24	5.00	236	1180.00	0.40	42	16.80
5.68	5.02	180	903.60	0	0	0

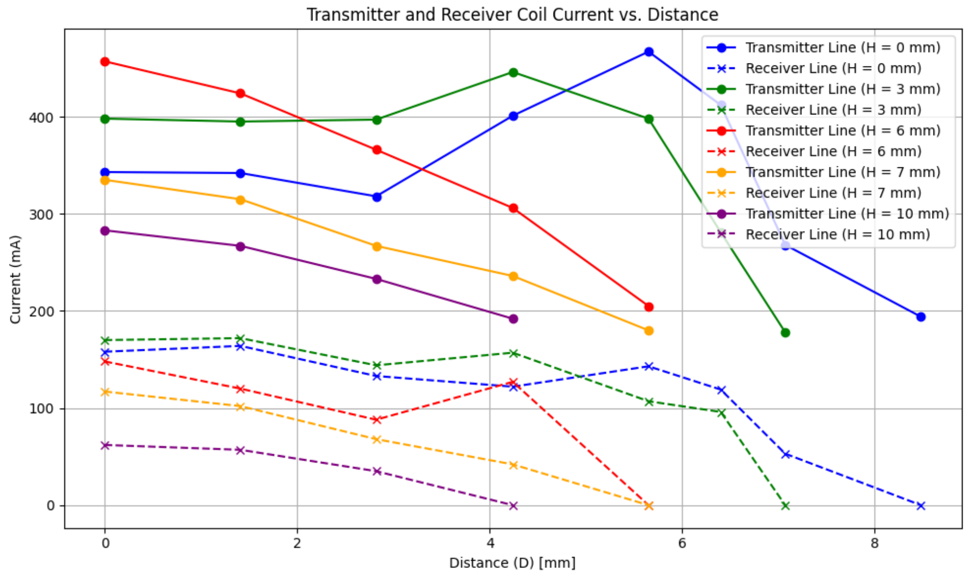
$H = 10\,\mathrm{mm}$

Distance (D) [mm]	Transmitter Coil Voltage (V)	Transmitter Coil Current (mA)	Transmitter Coil Power (mW)	Receiver Coil Voltage (V)	Receiver Coil Current (mA)	Receiver Coil Power (mW)
0	4.97	283	1407.31	1.30	62	80.60
1.41	4.98	267	1330.26	1.04	57	59.28
2.82	4.99	233	1162.67	0.20	35	7.00
4.24	5.01	192	961.92	0	0	0

METHODOLOGY

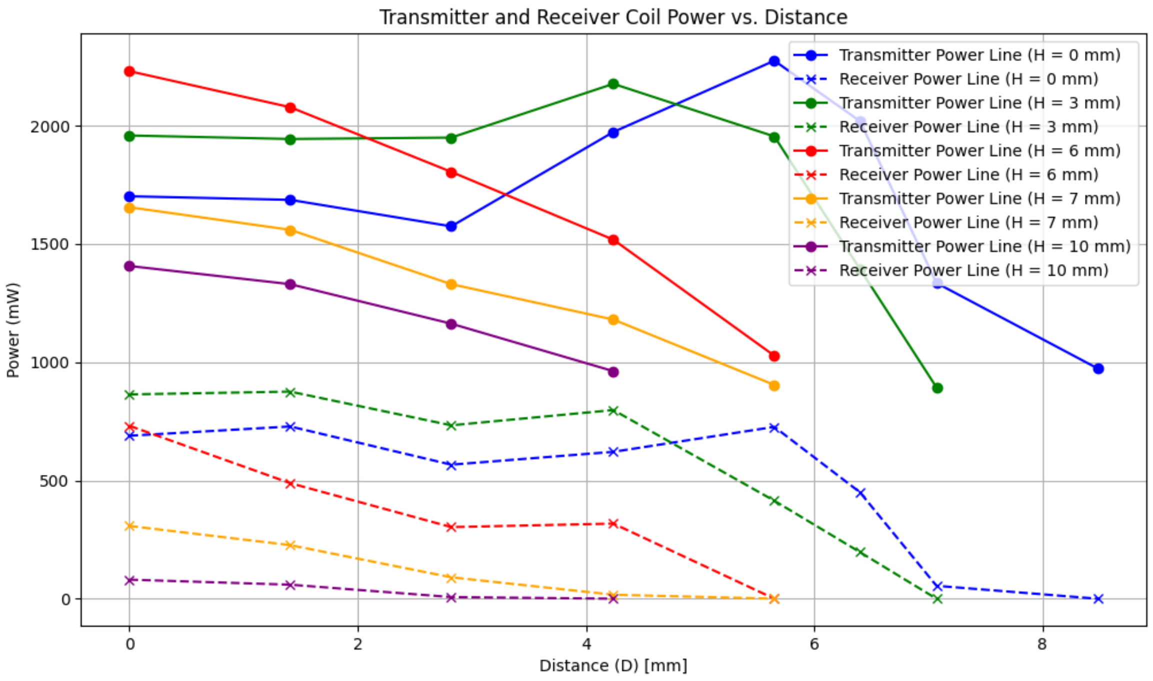
Hardware implementation: Graph for Voltage(V), Graph for Current(mA)

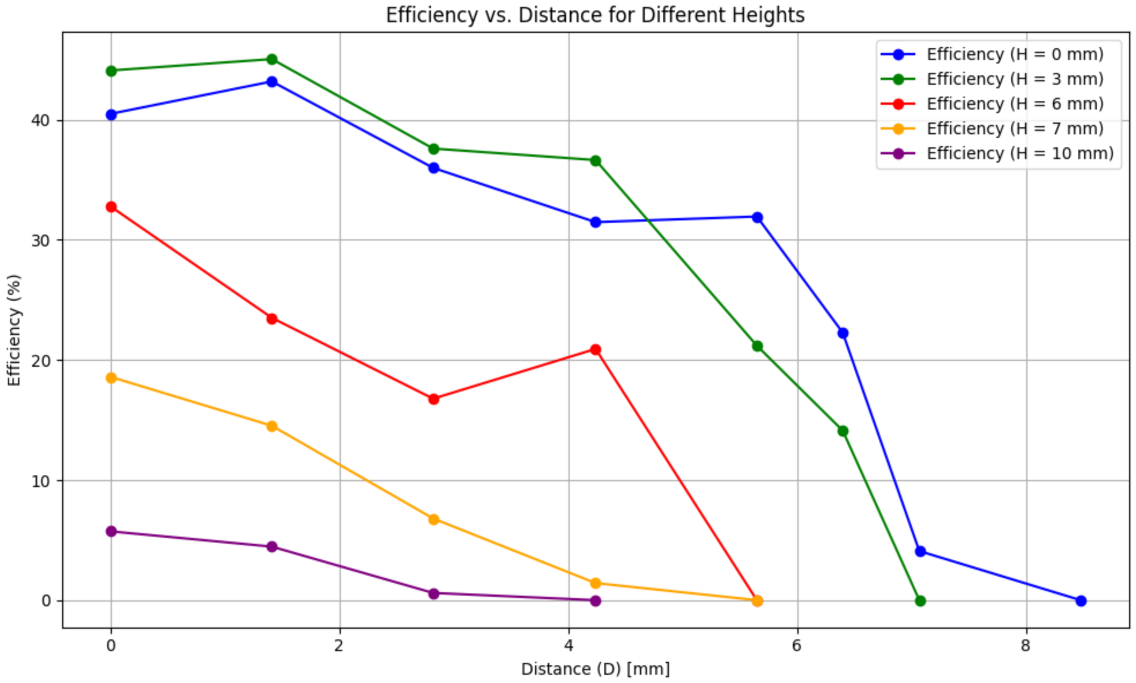




METHODOLOGY

Hardware implementation: Graph for Power(mW), Graph for Efficiency(%)





RESULTS & DISCUSSIONS

Insights from Prototype Testing: Key Results

- Efficiency decreases as the distance from the center of the coil increases.
- At heights of H = 6 mm, 7 mm, and 10 mm, the efficiency drops significantly compared to smaller heights like H = 0 mm and 3 mm.
- Power loss increases above a height of 6 mm, and there is no power transfer at heights exceeding 10 mm.
- The maximum power transfer occurs at H = 3 mm with an efficiency of 40%

CONCLUSIONS

•In conclusion, this work addresses critical challenges in wireless EV charging by incorporating camera-based misalignment detection and hardware validation.

•By improving efficiency, reliability, and automation, it enhances the practicality of wireless charging for electric vehicles, contributing to sustainable transportation.

•The system ensures optimal power transfer, reducing energy loss and increasing charging accuracy.

• Additionally, its integration with smart systems and green technologies supports the development of intelligent transportation networks.

FUTURE WORK

- In the following tasks, we will design a mechanism for the charging pad to move along the X and Y axes to automatically self-align with the vehicle's charging coil.

- We will also design a camera-based system that detects misalignment in all three axes, X, Y, and Z, thus automatically aligning the charging pad without the need for manual adjustments.

- Currently, the system's efficiency is around 40%. In future developments, we aim to double this efficiency by refining the alignment and power transfer processes, enhancing overall system performance.

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Thankyou