Smart Wireless Charging

Rohan Nana, Christian Rich, Nicholas Ni, Antonne Williams

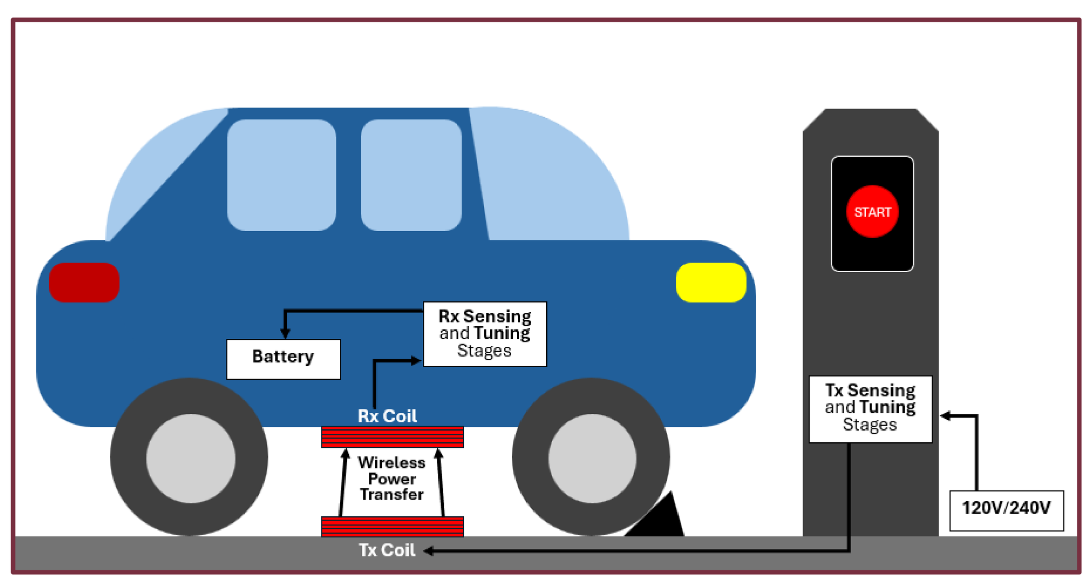
Electrical and Computer Engineering

Florida State University Panama City

Abstract

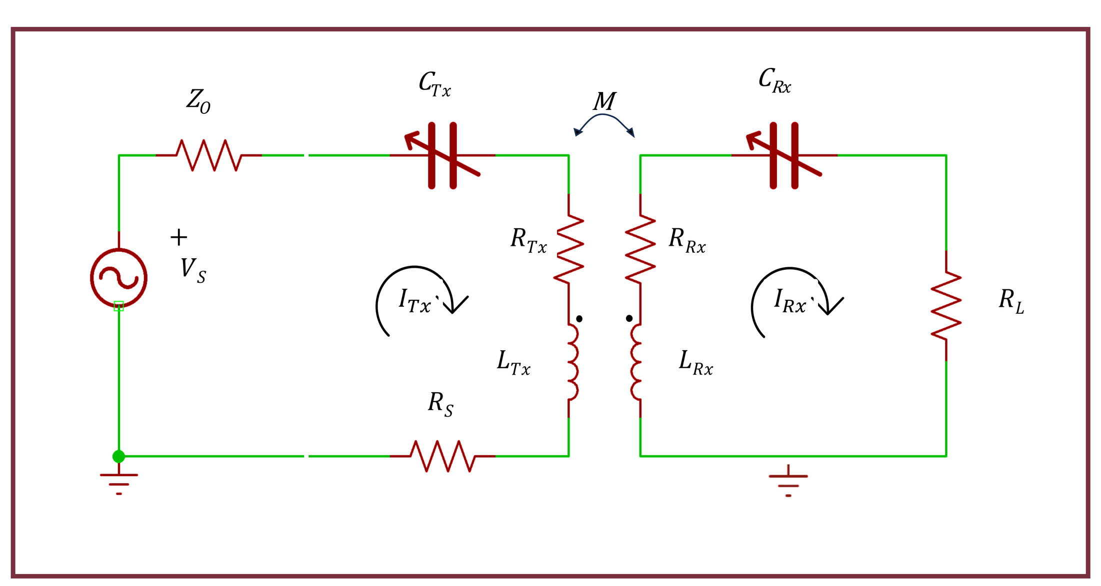
With the growing adoption and increasing market capitalization of electric vehicles (EVs) and autonomous systems, the development of innovative and user-friendly wireless charging solutions has become a critical priority. Current challenges with the technology include users needing to park perfectly over a transmitting coil, decreasing convenience and practicality. This project presents an adaptively tuned wireless charging system that leverages machine learning for real-time tuning. The system is fully automated, allowing users to monitor charging metrics remotely while eliminating the need for precise parking or vehicle alignment, as it will compensate for any coil misalignment. This technology aims to improve the way EVs are charged, enhancing user convenience and accessibility on a global scale.

Introduction

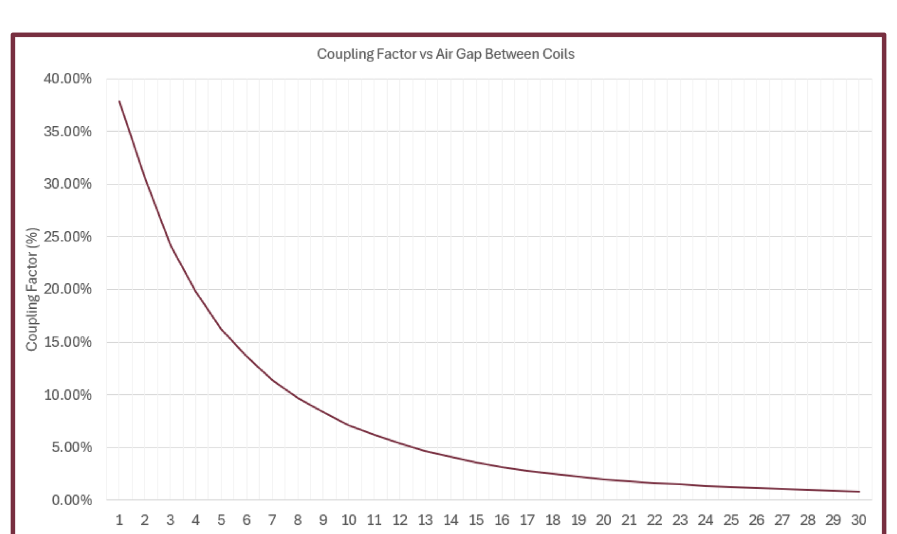


High Level Smart Wireless Charging Diagram

This project is geared towards golf carts (EVs) and solves the challenge of parking misalignments with the current technology through an automated, user convenient tuning system. Users can park in different areas while still charging at the same power transfer rate.



A **resonant inductively coupled circuit** is used, so the system can be tuned when mutual coupling changes due to distance. Z_M and **k** are used to define how much magnetic flux is being coupled between the two coils.

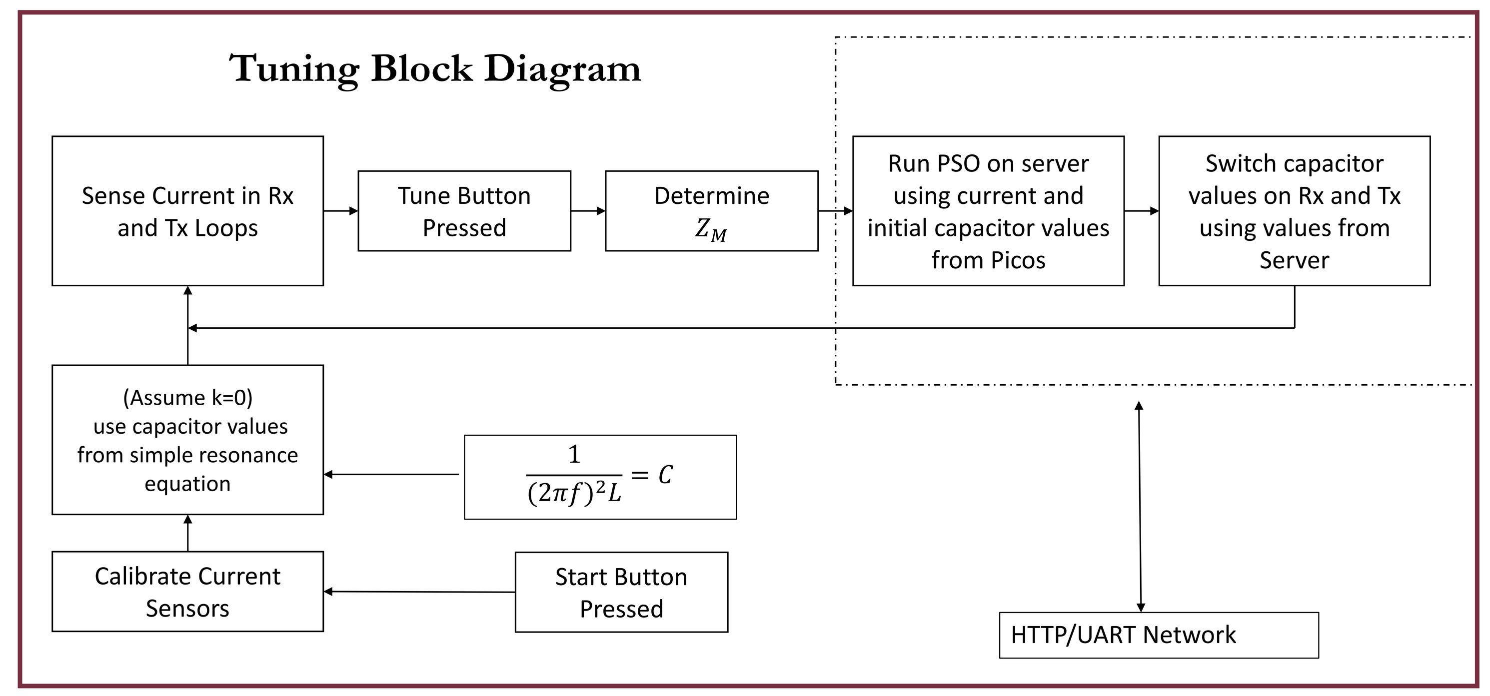


$$Z_M = \frac{I_{Rx}}{I_{Tx}}\left(R_L + Z_{C_{Rx}} + R_{Rx} + Z_{L_{Rx}}\right)$$

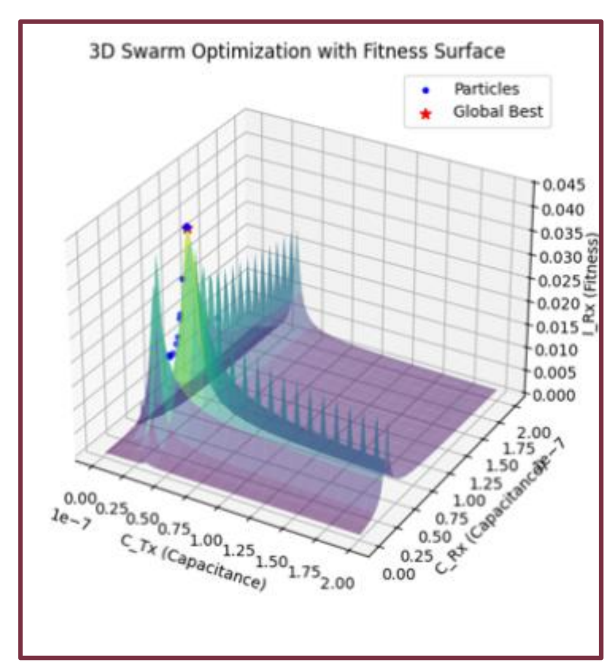
$$k = \frac{Z_M}{(2\pi f)(\sqrt{L_{Tx}L_{Rx}})}$$

Distance exponentially effects the coupling factor **(k)** between the Tx and Rx coils. This project addresses this issue and allows for the same power transfer even within 10cm air gap deviations.

Methods



The system automatically compensates for the change in mutual inductance. Current is a feedback parameter used to monitor real time power transfer. If current moves outside the 5% threshold, the retuning process is initiated.



The specific mutual coupling factor is found using the Z_M equation, which generates a 3-D plot of I_{Rx} as a function of C_{Tx} and C_{Rx}. A new 3-D plot is generated as distance changes, hence, why the optimal capacitor values vary.

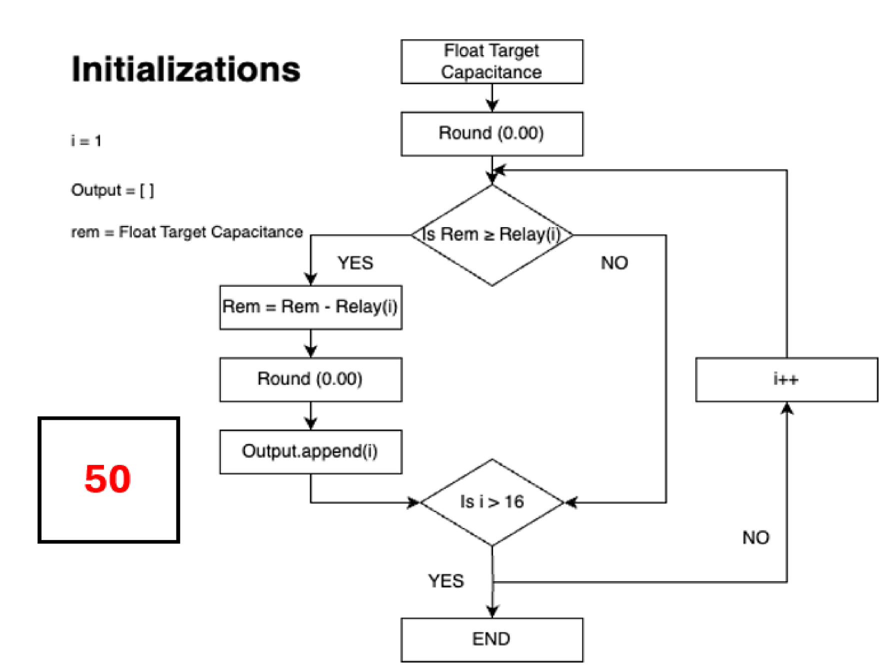
A particle swarm optimization algorithm is used to find the optimal capacitor value pairs to maximize the function. These values are sent over the communication network, and the relays switch to those capacitor values.

$$\rightarrow I_{Rx} = \frac{Z_M V_S}{\left(R_L + Z_{C_{Rx}} + R_{Rx} + Z_{L_{Rx}}\right)\left(Z_O + Z_{C_{Tx}} + R_{Tx} + Z_{L_{Tx}} + R_S\right) - Z_M^2}$$

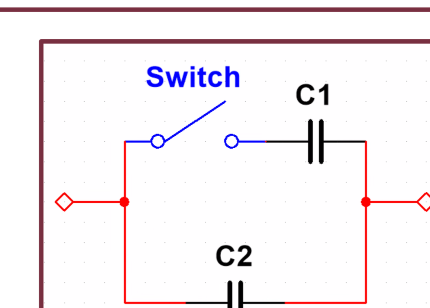
Capacitor Value Switching Process

Capacitor Bank (nF)

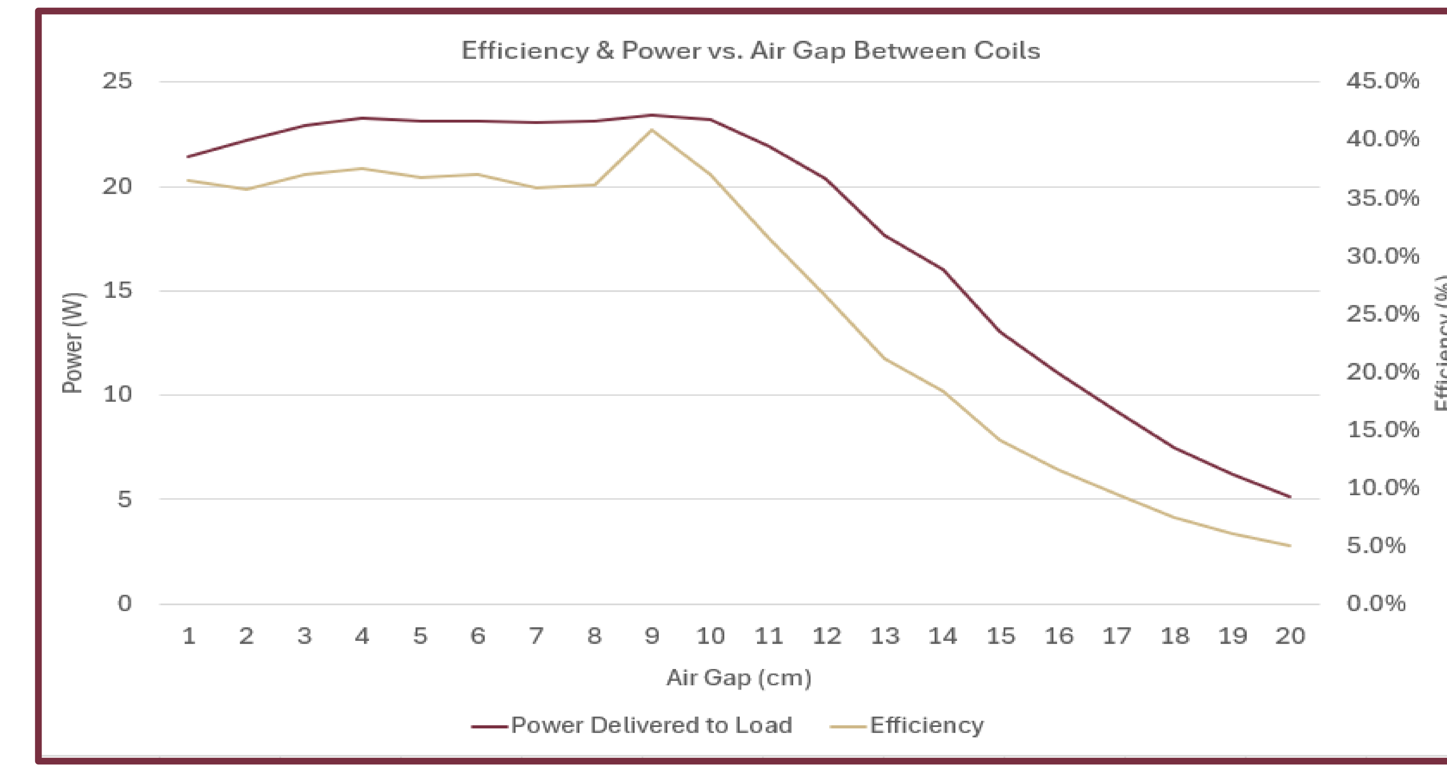
40 1	4 5	0.4 9	0.04 13
30 2	3 6	0.3 10	0.03 14
20 3	2 7	0.2 11	0.02 15
10 4	1 8	0.1 12	0.01 16



Digital relay boards are used for switching to specific capacitor values throughout the tuning process. The state diagram outlines the algorithm used to determine which relays need to be active in order to achieve a specific capacitor value.

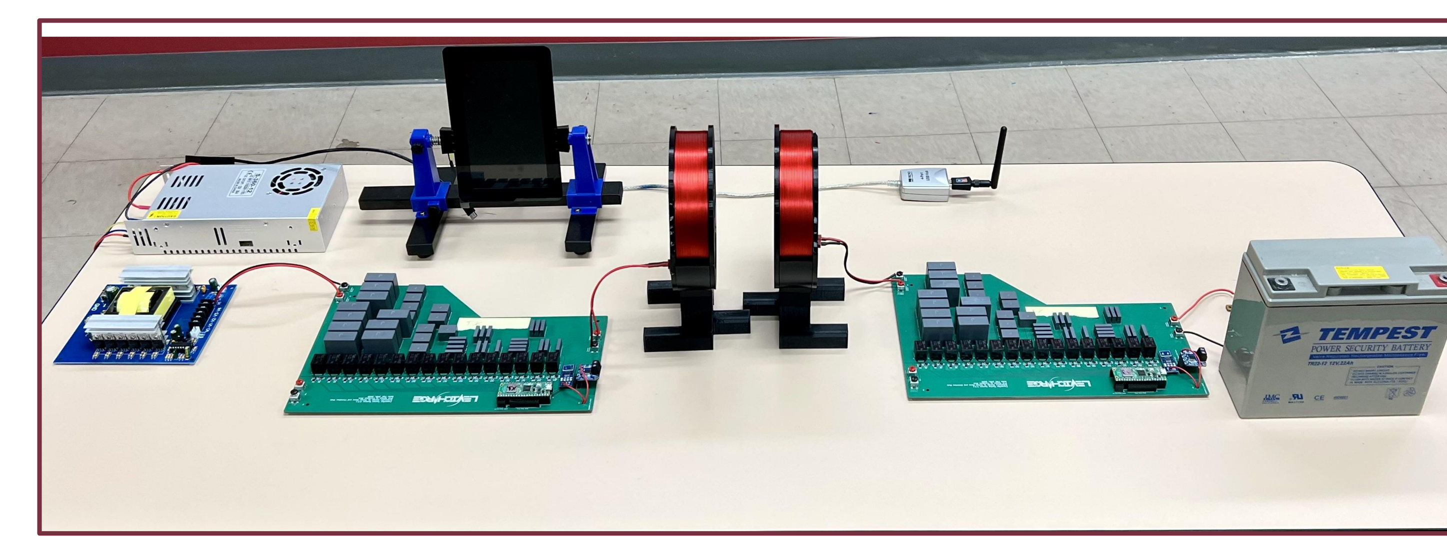


Results



Wireless power transferred to a 10-ohm load and the efficiency with varying air gaps.

The coils can be moved up to 10cm away from each other while the power transfer and efficiency remains relatively constant using the Levicharge tuning system. All values along the curve are after the optimization stage, and optimal power does not equate to greatest efficiency.



This research into near field resonant magnetic coupling has proven that power can remain constant even with coil misalignments. This has implications in the electric and autonomous vehicle industry as parking within a small threshold for coil alignment is not practical in the real world. Future work on the project would include efficiency and power transfer optimization to make the technology more viable on a large scale. The tuning process and ideas presented in this poster is a novel design created by the team and with further work can open doors for future research and development breakthroughs.

Acknowledgments

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All software, hardware, and data presented in this poster came about through research in the lab. All system components were designed and built by the Levicharge FSUPC Electrical Engineering senior design team.