Wireless Charging in a Dynamic Environment for Electric Vehicles

Sandeep Ushkewar
Department of Electrical Engineering
SVKM's Institute of Technology,Dhule
Maharashtra,India
sueedacademiccoordinator@gmail.com

Gaurav B. Patil
Department of Electrical Engineering
SVKM's Institute of Technology,Dhule
Maharashtra,India
gauravpatilee@gmail.com

Vishal Moyal
Department of Electrical Engineering
SVKM's Institute of Technology,Dhule
Maharashtra,India
vishalmoyal@gmail.com

Abstract— **Electrical vehicles require too much time to recharge their batteries, so to accommodate our busy schedule the conventional method of electric vehicle battery charging is replaced by "Dynamic Charging" The work presented involved the expansion of a novel type of wireless power transmission device to ensure high-efficiency battery charging stations for electric cars. A research project will look at the efficiency of traditional battery charging systems. In this paper, the finite element analysis is done by ANSYS simulation software. The static and dynamic modeling of the suggested wireless power transfer technique is the study's most important finding. A new model is created and describedthat takes into account both static and dynamic issues. This article will aid in the growth of future electric vehicle infrastructure.**

Keywords—Electric Vehicle, Wireless Power Transfer, Dynamic Wireless Charging System, Magnetic Resonance Coupling

I. INTRODUCTION

Because of the rising need for electricity, scientists have begun to look into alternative energy sources for power generation. In today's electricity grid, wind turbines and photovoltaic cells have progressively replaced coal, oil, and natural gas-based power generation. As a result, the means of mobility have moved from traditional gasoline cars to electric automobiles. Taking into account a variety of environmental concerns, the Indian government has chosen to have electric cars on Indian highways by 2030. The objective is for a minimum of 40% of buses and 80% of two-wheelers on the road to be electric by 2030. As the Indian government's Ministry of New and Renewable Energy announces numerous programs and subsidies for electric cars, the acceptance of electric cars (EVs) has increased dramatically. The primary issue with electric vehicles is battery charging. The problem is that electric cars require a simple and reliable charging system. Users are dissatisfied with the predictable recharging mechanism at home or in public places since a long recharge time is always required. Wireless car charging, with a few exceptions, is a better form of smartphone charging. An electric vehicle [EV] may be robotically charged via wireless inductive charging, which eliminates the need for cables or any other sort of wiring. Dynamic charging, also known as inductive charging of electric cars at high power levels, allows charging of electric vehicles while in a signal.

While moving down the highway, electric cars immediately charge the battery, reducing the battery's recharging time. A general wireless charging system with a simple, dense, low-cost circuit design that transports energy using induced magnetic flux formed between the power transmissions and receiving sides [1].

It is advised to adopt dynamic inductive power transmission technology. [2] Wireless charging was put to the test in a range of settings, including distance and alignment, and it was created to be 90 percent efficient. [3]. Source. Electric vehicles are becoming adopted quickly. economic and policy analysis. Electric vehicles (EVs) with dynamic charging have the potential to lessen anxiety while also reducing the necessary battery capacity for an acceptable range. The billing process is simple and fully automated. It does not need human intervention. It is small and compact when compared to a wired system. When compared to a standard wired system, the wireless scheme is more cost-effective. Because there is no touch, it takes up less space and may be placed below the surface. The electrical connections are hidden. It has the potential to lessen the danger of electrocution from electrical cables. In this study, the wireless recharging technique based on a moving vehicle was expanded upon and specified. Drivers respond favorably to the super-fast recharge station in terms of recharge time, but it is not always advised, particularly in terms of battery protection and durability.

II. METHODOLOGY

Generally, there are five main methods castoff for wireless charging of the electric vehicle.

[1] Magnetic induction
[2] Microwave
[3] Capacitive coupling
[4] Magnetic resonance coupling
[5] Magnetic Induction Coupling

Considering the advantages and limitations of each method stated above the Magnetic Resonance Coupling is selected for our software & future hardware model. As shown in Fig.1 Flux transfers from the main to the minor coil. The loops in the pavement use electricity to create a magnetic field.

978-1-6654-9291-1/22/$31.00 ©2022 IEEE

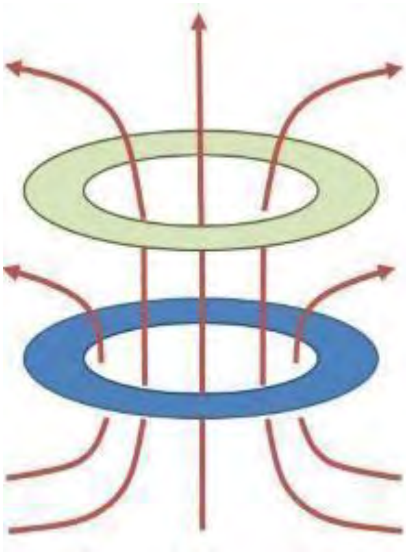

Fig.1 Concept of Magnetic Resonance Coupling

As illustrated in Fig.1 The magnetic field lines often protrude when they cross an air gap. Because magnetic fringing is all that exists when magnetic field lines travel through non-magnetic materials or the air, it is because they oppose one another. It ensures that a coil on a vehicle receives flux and is able to transform it back into electrical energy. [4] The motor's battery is charged using the energy that is generated. Smaller batteries possibly reduce capital costs. Reduces concerns of a range of anxiety. Heavier e-Vehicles such as trucks and buses are realistically possible [5,6]. Reduce battery recharging time. Smaller batteries are environmentally beneficial and can potentially reduce capital expenses [7].

III. THE IMPACT OF WIRELESS POWER TRANSMIT DUE TO COIL SPEED AND POSITION

It is well known that the wireless charge system for an EV or other type of electric system consists of two parts [8]. The first component is connected to the primary coil, commonly known as the transmitter, and the second component is connected to the secondary coil, also known as the receiver [9,10]. The mathematical modelling and simulation of wireless charging systems are the main topics of this section. This modelling was different from what was previously available. In fact, we've developed a model that can determine how much power the wireless charging system consumes even when the car is moving. The term "dynamic modelling" originated from the model that was created in that scenario, which took the vehicle's speed into consideration [11,12]. The size of the coils and the amount of power injected are determined by the distance between the source and the receiver. The degree of overlap between the coils must be taken into account when trying to increase receiver power [13,14].

Fig.2 displays the flux trend between two simultaneous coils for two different secondary coil positions. The amount of transmitted flux is substantial despite the fact that the distance in between centers of the coils is the shortest (d_1= 0). In Equations (1) to (3), the scientific replicates for this system are shown (9) The flux produced by the primary coil is 1, and the secondary coil records a flux of 2. This component regulates the locomotive force in the receiver component. For such flux in the main coil, a physical-mathematical computation has been made (1).

$$\emptyset_1(t) = N.S.B(t) = (\frac{\mu_0 .S.N^2}{e})i_1(\text{t}) \;..... \;(1)$$

The flux pattern for two different types of parallel coils Where l denotes the solenoid's length, N its number of turns, S its surface, I its current, B its magnetic field, and 0 its magnetic constant If the flux transmission line is assumed to be linear, we may observe that the acquired flux in the secondary coils is exactly equal to 1. Therefore, it is probably going to establish the engine force upon that secondary coil, denoted by e1. The equation provides a description of the electromotive force (2)

$$e_1 = \frac{d\phi_1}{dt} = -L\frac{di_1}{dt}e_1 = -d\emptyset_1 \;..... \;(2)$$

The equation may be used to express the new flux expression in the primary coil (3)

$$\emptyset_1\ (t) = L.i_1(\text{t}) \;..... \;(3)$$

Only when the dual coils are on the similar axis does 2 Equal 1.

The flux obtained in the secondary coil "attached to the vehicle" is expressed as specified since the dual coils in a mobile vehicle are not confused. Where acquired flux in secondary coil is expressed as a percentage. This was due to a number of variables, including car speediness and coil settings.

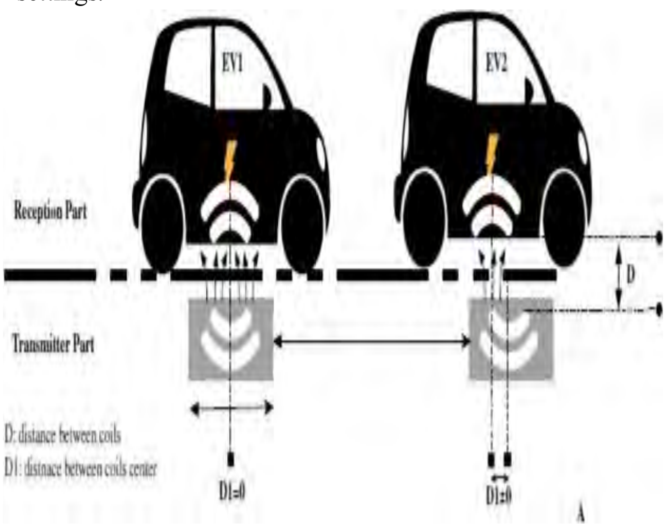

Fig.2 The shape of transmitted magnetic flux for both primary and secondary coil position

$$\propto = 0 \text{ if } d_1 > d_c$$
$$\propto = 1 \text{ if } d_1 = 0$$
$$0 < \propto < 1 \text{ if } 0 < d_1 < d_c \quad .....(4)$$

The secondary coil's portioned output voltage will be as specified in Equation (5)

$$U_2\,(\mathrm{t}) = R_2 . i_2(\mathrm{t}) + \propto . L . \frac{di_1\,(t)}{dt} \quad ......(5)$$

The resistance of the secondary coil is denoted by "R2." The secondary coil is connected to the vehicle, thus when the vehicle travels, so will the secondary coil's location in relation to the primary coil. Calculating the transmitted flux amount requires an equation. When the secondary coil is moving, the amount of conventional flux and power is influenced by the vehicle's speed. Equation establishes the likely flux-transferred time among the dual coils (6). It is evident that a variety of parameters, including the vehicle as depicted in Fig. 2 and the distance among coils, as determined by "Dcoil," affect the flux-transferred time.

$$T_{transfer} = (\frac{D_{coil.10^{-5}}}{V_s}).3600 \quad ......(6)$$

Using those equations, the entire duration of the conducted flux between two coils is calculated for the purpose of determining coil parameters and vehicle speed. We give four different instances for different coil diameters: 10, 30, 50, and 80 cm. For slower speed numbers, like 20 km/h, Figure 14 demonstrates The equivalent energy transit time from the the receiver to the transmitter is faster for larger speed numbers, such 100 km/h.

While the car is still, the transferred time is evident; however, as the car's speed rises, the energy-transferred time rapidly decreases. In order to calculate the injected power inside the battery, a mathematical model will be used in this investigation. The appropriate system's construction is shown in Figure 15. Therefore, it is possible to estimate the quantity of power obtained and then compute the battery's state of charge after entering the coils' number and the vehicle's speed. This section demonstrates the scientific calculation for how vehicle speed affects the SOC value:

$$U_2\,(\mathrm{t}) = R_2 . i_2(\mathrm{t}) + \propto . L . \frac{di_1\,(t)}{dt} \quad ......(7)$$

$$\propto = \sin(x)$$

$$\mathrm{X} = [0\ T_{transfer}] \quad ......(8)$$

$$\mathrm{K} = \propto . L = f(V_s) \quad ......(9)$$

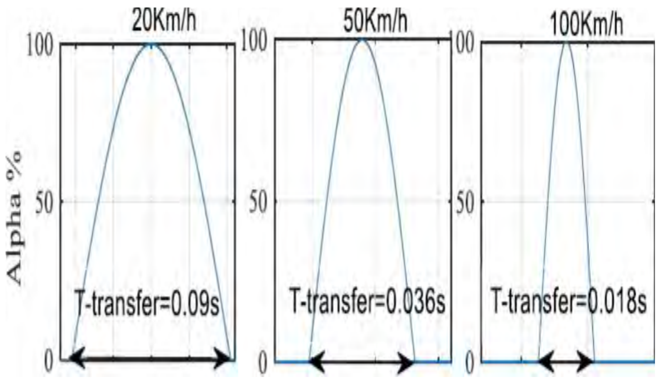

Fig.3. Flux evolution and corresponding time of energy transfer for each of the three speeds

It is clear from Fig. 3 that the wireless generator's output power is minimal despite the high vehicle speed. The opposite holds true with the slowest speed. This assertion will be supported by the simulation results in the following section.

IV. Simulation results

In order to consider the electric behaviour and magnetic response of such a system, researchers have used concept of Magnetic Resonance Coupling (MRC), as can be seen in Fig.1, and designed the primary and secondary coils in ANSYS simulation software, as shown in Fig.2 [8]. The finite element analysis was carried out using ANSYS simulation software. An inductive coupling WPT system's efficiency is inversely correlated with the separation between the transmitter and receiver.

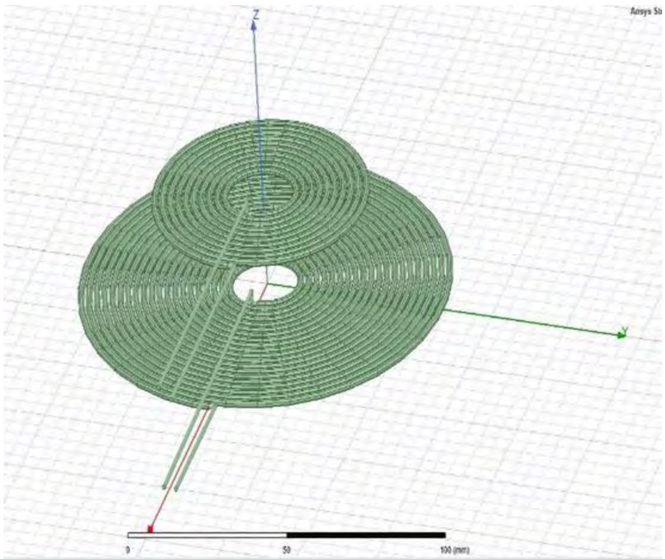

Fig.4 Primary - Secondary Coils

To handle more power (through the inductive coupling of Wireless Power Transfer), the number of windings (both in the main and secondary coils) should be increased, as illustrated in Fig. 4.

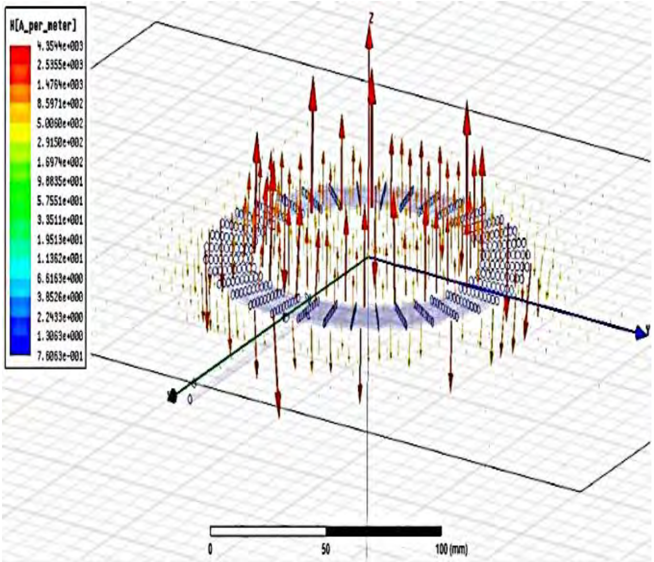

Fig. 5. Magnetic field intensity direction around Tx coil.

Fig. 5 shows magnetic field intensity, also known as magnetic field strength, which controls the magnetizing force in terms of the coil's length and current capacity. Circular designs continue to be the most common for static EV charging applications. It has a lower coupling than other similar-sized coil designs across corresponding air gaps. Circular designs continue to be the most common for static EV charging applications.

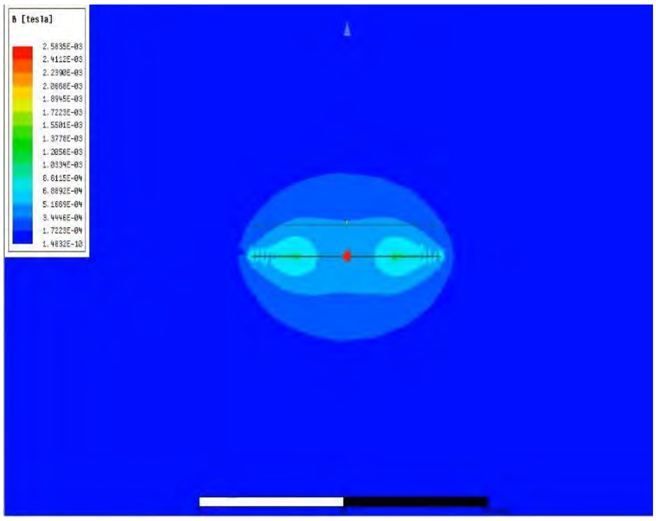

Fig. 6. Flux density pattern around the Tx coil

The quantity of magnetic force produced in the coil as a result of magnetic force is shown in Fig. 6. Around the Tx coil, the flux density pattern is examined. the transmitter and receiver are separated by a distance inversely related to the effectiveness of an inductive coupling wireless power transfer system [9].

The number of windings are increased to handle additional power through inductive coupling WPT. (both in primary and secondary) should be increased. The last two circuits are not based on inductive coupling [10].

In this manner, the magnetic field strength and flux density are investigated of the Tx coil, taking into account both the magnetic field's influence and the resulting magnetic field, as illustrated in Fig.7. Using the co-simulation features of ANSYS software for finite element analysis and electric simulation to evaluate the electric and magnetic responses of such a system at thesame time. Electric stimulation is utilized to regulate the motion of the receiving coil and drive the emitting coil in this work, and ANSYS software is used to depict the system reaction in terms of the induced field.[11]-[12].

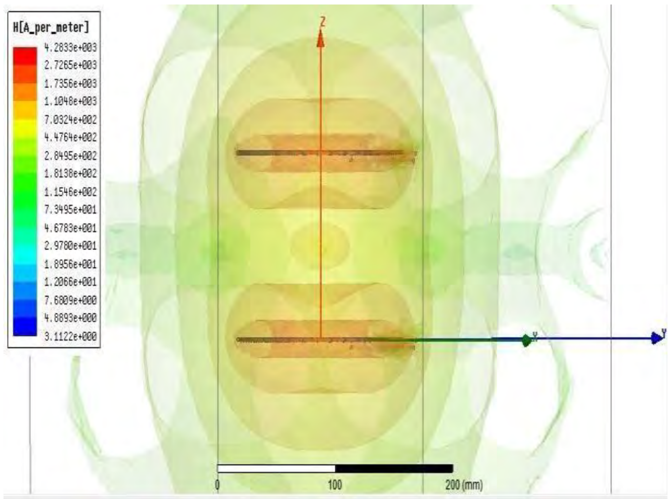

Fig. 7. Resultant magnetic field during WPT

The following findings are extremely useful in defining the form and scope of the Tx coil and receiver, as well as the distance from the Tx at which magnetic flux is greatest. The standardization of magnetic field, size, and form power pads will also benefit from these findings.

V. Conclusion

A quick examination of the static and dynamic wireless charging (DWC) methods, as well as their efficacy in relation to numerous variables. Power transmission, coil design, operating frequency, and compensation topologies are all technical considerations. This research developed and characterized the efficiency of a wireless recharging system based on a moving vehicle. Furthermore, having two coil receivers beneath the EV is an advancement in the approach, which was thoroughly detailed. The batteries utilized in today's electric vehicles could be solved by Dynamic Wireless Power Transfer (DWPT).

Acknowledgement

Authors would like to thank Principal of SVKM's Institute of Technology, Dhule, Maharashtra, India for providing research facility at SVKM’s IOT Dhule campus.

REFERENCES

[1] M. Budhia, G. A. Covic and J. T. Boys, "Design and Optimization of Circular Magnetic Structures for Lumped Inductive Power Transfer Systems," in IEEE Transactions on Power Electronics, vol. 26, no. 11, pp. 3096-3108, Nov. 2011.

[2] J. Dai and D. C. Ludois, "A Survey of Wireless Power Transfer and a Critical Comparison of Inductive and Capacitive Coupling for Small Gap Applications," in IEEE Transactions on Power Electronics, vol. 30, no. 11, pp. 6017-6029, Nov. 2015.

[3] A. Foote, B. Ozpineci, M. Chinthavali and J. Li, "Sizing dynamic wireless charging for light-duty electric vehicles in roadway applications," 2016 IEEE PELS Workshop on Emerging Technologies: Wireless Power Transfer (WoW), pp. 224-230, 2016.

[4] T. Imura and Y. Hori, “Maximizing air gap and efficiency of magnetic resonant coupling for wireless power transfer using equivalent circuit and Neumann formula,” IEEE Trans. Ind. Electron, vol. 58, no. 10, pp. 4746–4752, Oct. 2011.

[5] Y. J. Jang, Y. D. Ko, and S. Jeong, “Creating innovation with systems integration—Road and vehicle integrated electric transportation system,” in Proc. IEEE Int. Syst. Conf., 19–22 Mar. 2012, pp. 1–4.

[6] S. Mohrehkesh and T. Nadeem, “Toward a wireless charging for battery electric vehicles at traffic intersections,” in Proc. 14th Int. IEEE Conf. Intell. Transp. Syst., 2011, pp. 113–118.

[7] S. Jeong, Y. J. Jang, D. Kum and M. S. Lee, "Charging Automation for Electric Vehicles: Is a Smaller Battery Good for the Wireless Charging Electric Vehicles," in IEEE Transactions on Automation Science and Engineering, vol. 16, no. 1, pp. 486-497, Jan. 2019.

[8] Y. J. Jang, E. S. Suh, and J. W. Kim, “System architecture and mathematical models of electric transit bus system utilizing wireless power transfer technology,” IEEE Syst. J., (2015).

[9] T. Jitson and S. Cheapanich, "Study of Dynamic Charging for Electric Vehicles Using Stationary Wireless Power Transfer Charging," *2021 9th International Electrical Engineering Congress (iEECON)*, 2021, pp. 17-20.

[10] G. A. Covic, J. T. Boys, M. L. Kissin, and H. G. Lu, “A three-phase inductive power transfer system for roadway-powered vehicles,” IEEE Trans. Ind. Electron., vol. 54, no. 6, pp. 3370–3378, Dec. 2007.

[11] S. Jeong, Y. J. Jang and D. Kum, “Economic Analysis of the Dynamic Charging Electric Vehicle” in IEEE Transactions on Power Electronics, vol. 30, no. 11, pp. 6368-6377, Nov. 2015.

[12] Gaurav B. Patil, Sandeep Ushkewar, Ashwini Patil. (2022). “Computation of mass-spring-damper system using MATLAB” in Journal of East China University of Science and Technology, 65(3), 1004–1010.

[13] Yash Baviskar, Madhavi Patil and Sandeep Ushkewar, 2020, “Efficient Wireless Charging for Electric Vehicle, International Journal of Engineering Research & Technology (IJERT) Volume 09, Issue 10 (October 2020).

[14] Y. J. Jang, E. S. Suh, and J. W. Kim, “System architecture and mathematical models of electric transit bus system utilizing wireless power transfer technology,” IEEE Syst. J., (2015).