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Reconfigurable Converter Topologies for EV Fast Charging Stations

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ABSTRACT- Infrastructure for charging electric vehicles (EVs) is highly demanded due to the rising number of EVs on the road. Stations for charging electric vehicles are necessary for the ongoing transportation e-mobility. In particular, fast charging infrastructures increase the computing ability of transmission grids that are already under a lot of pressure. The market's current energizing foundation takes a ton of room and incidentally causes gridlocks, which raises the risk of mishaps and hinders crisis vehicles. The cost of installing this charging infrastructure increases significantly because the current system needs a lot of room. To resolve these issues, this work depicts a Reconfigurable Multidevice Interleaved Boost Converter Topologies with Placement Algorithm for adjusting and a space-proficient charging foundation. Because of its insignificant electromagnetic impedance, low input and result voltage swells, bidirectionality, high efficiency and dependability, delicate switching, commotion free activity, low exchanging loss, and high effectiveness, this topology is the most ideal decision for high-power EVs.

Keywords: Electric vehicle; Smart transformer; Multidevice Interleaved Boost Converter (MDIBC); Fast Charging station; Placement Algorithm.

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1. INTRODUCTION

Electric energy is a requirement because the modern way of life of humanity depends on its usage [1]. The growing population has led to an increase in the need for energy. The majority of the world's electrical needs are fulfilled by traditional sources, which are steadily running out and posing grave environmental risks. Many nations are working hard to identify alternative energy sources, such as solar power, wind power, etc., to reduce their reliance on conventional fossil fuels. The benefit of renewable energy resources (RER) is that they are sustainable for society and clean. Concurrently, the use of energy in the sphere of transportation is shifting from fossil fuel to electricity.

A way to utilize fewer fossil fuels is to employ a transportation system that runs on electric power. When compared to vehicles powered by fossil fuels, the operational costs of electric vehicles (EVs) are lower. Even though the government has launched a number of incentive programmes to encourage the purchase of EVs, the market's acceptance of EVs is still in its infancy. One of the main obstacles to the marketing of EVs is their poor charging infrastructure and limited battery capacity.

Due to space restrictions, installing a personal EV charger for each EV owner is not feasible. In addition, refuelling a conventional car takes much less time than charging an electric vehicle. The user may find it useful if a real-time CS recommendation shared information about the status of CSs, including charging options, energy costs, and travel times to the CS, among other things [2]. One of the most widely employed methods of energy conservation. There has been an increase in the integration of electric vehicles with bidirectional converters.

To alleviate traffic congestion and offer CS recommendations to EV users, research was conducted to propose a novel converter Topologies for Fast Electric Vehicle Charging Stations. [3] Additionally, it is anticipated that EV sales would rise quickly in the next years, from 3.1 million in 2020 to 14 million in 2025 [4]. Plugging into the power grid makes it easier to achieve reactive power support, ancillary services, peak load shaving, load balancing, and the integration of renewable energy resources [5]. Additionally, EV driving range can be matched with that of IC engine-based vehicles thanks to the development of dc fast and ultra-fast charging infrastructure. A good option for current sharing and raising the voltage for high power applications is an interleaved boost DC-DC converter.

Thus, the multidevice interleaved boost converter (MDIBC) is proposed as a reference for improvement, in minimizing the size of passive components, output voltage ripple, and input current ripple. [6] The presentation of optimization algorithm is one of the most current subjects being studied by researchers, industries, engineers, and countries for diverse optimization aims given the vast uses of optimization in numerous sciences. Most existing methods only looked at and discussed a small number of instances. [7]

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2. RELATED WORKS

Zhang et al. [8] examine the different charging connector types and difference the European and American guidelines at the same time. The novel plan technique utilized by Pandey et al. [9] for quick EV charging stations on a circumferential parkway likewise considers shoppers' inclinations for spatial and worldly versatility. Iyer et al. [10] give an information driven, reliable EV charging foundation plan system for private parking garages that considers the future unconventionality of EV charging conduct. The concept proposed by Janabi et al. [11] includes an improvement model and a battery's business case exchange station. Muttaqi et al. [12] develop the ideal battery buying and charging methods framework that modifies battery experience cost and working expense, including charging cost and client halting, by simulating charging tasks at a BSS with time-fluctuating interest for battery trade and time-moving costs for charging void batteries.

Pahlevani et al. [13] work revolves around a game plan thought and model for supporting EV gathering through robotized pack of battery exchanging at station for sharing batteries as a piece of a battery sharing affiliation, that would change into a critical piece of the clever organization. Habib [14] Give close consideration to where the best areas for charging stations are in urban areas. Suresh et al. [15] make sense of the improvement of an all-universal inductive charger (UIC) for electric vehicles. Zhou et al. [16] have examined and constructed a PV - based vehicle charging framework that is explicitly intended for smart homes and structures. As well as analyzing Indian government strategy, in addition to examining Indian government policy, Sorlei et al. [17] look at the issues with the infrastructure for electric vehicle charging.

M. Rezvanyvardom et al. [18] The DC-DC Boost converter without auxiliary switching is suggested in this paper as a voltage gain interlaced gentle operated design. The suggested topology achieves step-up characteristics without the use of a transformer, coupled inductor, voltage multiplier cell, switched inductor, or switched capacitor. N. H. Abu Khanipah et al. [19] To address the shortcomings mentioned above, the multi device interleaved boost converter (MDIBC) is presented in this study. In comparison to conventional DC-DC converters, the MDIBC provided great efficiency while reducing the size of the passive component and input ripple current. Xiang Gao and others [20] This study examines the potential effects of various functions on the placement of charging stations.

3. PROPOSED MODEL

The Reconfigurable Converter Topologies is a multiport, multiphase interleaved Boost converter that makes use of stage interleaving, two high-recurrence switches per intentionally easy line, and two additional switches. The quantity of equal gadgets required for each stage can be diminished by expanding the quantity of stages. To keep a managed yield in the converter, ordinary double circle, criticism linearization, and state-criticism regulators are commonly used in Reconfigurable Converter Topologies. Restricting volume, weight, current waves, capability, and cost are the fundamental arrangement issues in auto power electronic connection points (PEI). To satisfy design goals, it is anticipated that the Reconfigurable Converter Topologies major heavyweight components— high-power inductors, channel capacitors, and intensity sinks — will be decreased in size utilizing high exchanging frequencies and interleaving methods.

The main characteristic of Reconfigurable Converter Topologies is the reduction in the data current waves, which is made possible by the interleaving approach's use of the gate signals. Through the Reconfigurable Converter Topologies, many input sources are integrated to create a constant output voltage level. *Figure 1* shows how Reconfigurable Converter Topologies keeps the proper level of information current waves and the resulting voltage swells at a constant level without raising the value of detachable sections (capacitor, inductor channel circuit). Both ports in an Reconfigurable Converter Topologies share a common control and a common DC link capacitor scheme a typical heat sink, and. Reconfigurable Converter Topologies is more dependable than conventional topologies since there is a decreased chance of an electrical failure. The regenerative braking power may be used by the Reconfigurable Converter Topologies thanks to its a bi-directional power flow capability, which raises the system's overall effectiveness and efficiency. Another advantage of this converter design is that it may be applied to a single port with high power and voltage applications, such as directly connecting an HV battery to the inverter's DC connector, while maintaining the same effectiveness and dependability. Because of its adaptable control, little size, multipurpose capacities, high effectiveness, and further developed unwavering quality for BEVs, an ordinary 3-stage interleaved bidirectional DC/DC is right now normal in the application of automobiles. In contrast, the Reconfigurable Converter Topologies has a high component count, a converter that is sensitive to changes in the load current profile and has stability issues, and it is difficult to examine features under steady state and transient conditions.

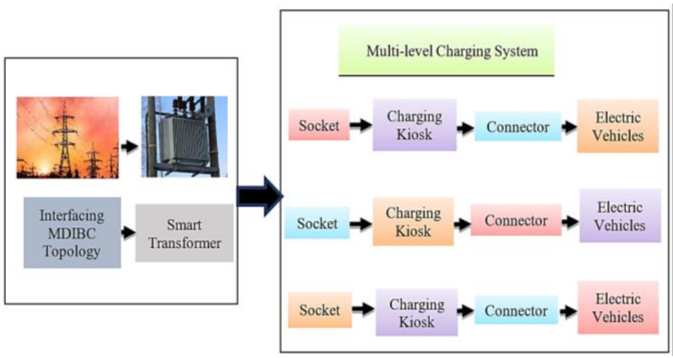

Figure 1: Proposed Architecture

3.1 Improved Multidevice Interleaved Boost Converter

It was determined that, even at very high ripple factors, the high-frequency ripple will have no impact on the functionality, behaviour, and lifespan of an FC. Further, the amplitude of the current ripple increases with the amount of additional power losses, making FC current ripple reduction even more crucial when building a converter. The enhanced MDIBC's proposed

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design, which is depicted in *figure 6*, intends to increase performance while decreasing FC lifetime and FC lifetime ripple.

The input signals are increased to 8 signals (S1 to S8) and will be dependently switched to 4 output signals (G1 to G4) to operate the standard MDIBC converter witches (SIGNAL MUX 4) is a signal multiplexer that is used. This will improve the conventional MDIBC to minimize the existing ripple amplitude and gain an additional double ripple frequency. The multiplexer's job is to choose and turn on one channel at a time. High speed logic gates are used in the design of the multiplexer digital circuits.

Typically, more switching devices are needed in the typical MDIBC in order to achieve a double ripple frequency and reduce current ripple amplitude. As a result, the system's price will go up. The converter can provide a further increase in ripple frequency and a reduction in ripple amplitude without adding more switches by enhancing the typical MDIBC with a signal multiplexer.

3.1.1 MDIBC Converter Topologies for BEV

By adopting a unique multiplex controller topology to operate the Improved MDIBC, this technique achieves a quadruple ripple frequency and substantially reduces without increasing the quantity of switches, the ripple amplitude. The Reconfigurable Converter Topologies' specification values for the passive parts of BEVs as displayed in the data *table 1*.

Table 1: Specifications of Reconfigurable Converter Topologies

Symbols	Specifications
V_{in}, Input Voltage (V)	250,200
V_{out}, Output Voltage (V)	400
F_{sw}, Switching Frequency (kHz)	20
IL_{max}, Inductor Current (A)	100
ΔILmax, Inductor current ripple	10
ΔVout, Output Voltage Ripple	4
N, Number of Phase	3
N, Turns ratio	-
P_o, Output Power (kW)	30
D, Maximum Duty Cycle	0.50
L, Inductor (H)	187.5, 160
C, Capacitor (F)	160

The duty cycle of each switch in a reconfigurable converter topology is D1 = D2 = D. Additionally, all of the inductors have the same value, LS = LB = L. In this case, m stands for the parallel switches. Topology of the Improved MDIBC shown in *figure 2*.

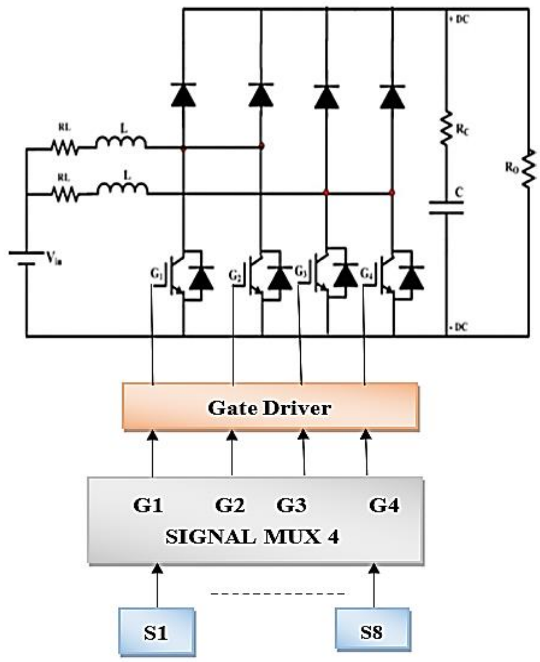

Figure 2: Topology of the Improved MDIBC

Boost ratio, often referred to the converter's voltage gain is described as follows:

$$V_0 = \frac{V_{in}}{1-mD} \quad (1)$$

As shown below, input current can be calculated:

$$I_{in} = \frac{I_o}{1-mD} \quad (2)$$

$$D_{max} = \frac{1}{m}\left(1 - \frac{V_{in}}{V_{out}}\right) \quad (3)$$

Selection of inductor and capacitor:

$$L = \frac{V_{out} \times (1-m_D) \times D}{N \times f_{SW} \times \Delta I_{Lmax}} \quad (4)$$

$$C = \frac{V_0 \times D}{N \times f_{SW} \times R \times \Delta V_0} \quad (5)$$

3.2 Restrictions on the grid and grid support provided by fast charging station

The grid limits were described in this section and are pertinent given the rising penetration of vehicle charging stations. The effects of grid voltage and ampacity constraints on grid devices are discussed in the sections that follow, Furthermore the possibility for inverters connected to the grid to help the grid. Grid voltage must remain within a specific maximum deviation to guarantee the grids' safe operation. For instance, the German grid code permits 10% max voltage fluctuation This necessitates designing the grid in such a way that it also accounts regarding the grid's active power demand P and reactive power demand Q in order to ensure that this is guaranteed. Rapid charging stations and a typical MV radial grid shows in *figure 3*.

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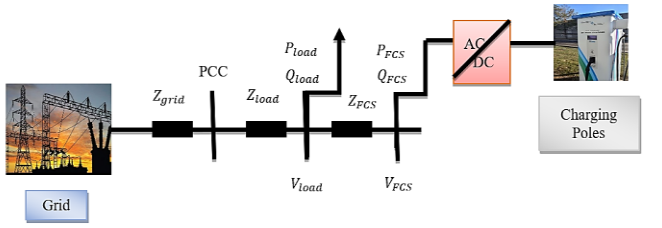

Figure 3: Rapid charging stations and a typical MV radial grid

Table 2. Dimensions of the MV Radial Grid

Parameters	Specification
Base Voltage	10 kV
Base Power	1MVA
Z_{grid}	0.01pu
Z_{load}, Z_{FCS}	0.02pu
$P_{load} + jQ_{load}$	(3+j0.5)pu

3.2.1 Placement Algorithm for Fast Charging

In this paper, an FCS placement algorithm installation is proposed. According to the placement selection concept, the FCS installed at the chosen sites in a grid network will have the greatest ability to regulate the network in comparison to FCS installed at other locations with an equivalent power rating. Therefore, fv and fc are the definitions of the objective functions. The two goals are examined independently. The index EI is described as the following when assessing the performance of several locations:

$$EI = \mu_v . f_v + \mu_c . f_c, \quad (6)$$

The weights μ_v and $\mu_c$stand for the voltage stability and current violation prevention priorities. All of the numbers must add up to one.

$$\mu_v + \mu_c = 1 \quad (7)$$

The investigation of FCS placement that maximizes the allowable charging energy of HCFs is the goal function for either voltage support or current congestion management. The definition of the optimization goal is

$$f = max \int_t^T (\sum_{n_p=1}^{n_p,max} (P_{n_p}(t) - Pn_p(\text{t})). \text{dt}) \quad (8)$$

Every node n_p It is believed there are m_{np} HCF accessible, each with a p charging power on demand. Maximum power permitted for charging $P_{n_p}(t)$ can be characterized as

$$P_{n_p}(t) = m_{n_p}(t) \quad (9)$$

Where $m_{n_p}(t)$ is the maximum allowed HCF. The allowed quantity of $m_{n_p}(t)$HCF is believed to be the same when np ∈ Np and must be mindful

$$m_{n_p}(t) \le M_{n_p} \quad (10)$$

The constraint in this study necessitates that the current flowing through the sub-station connecting the grid to the main network be less than the ampacity that is permitted.

$$I_{grid} \le I_{grid}^{max} \quad (11)$$

The power flow equations are included in the equality constraints.

3.3 Algorithms for Implementation

Implemented algorithms on server side are capable of regulating charging sessions with dynamic arriving time, departure time and varied price preferences. For explanation, the simplified versions of implemented algorithms are illustrated below

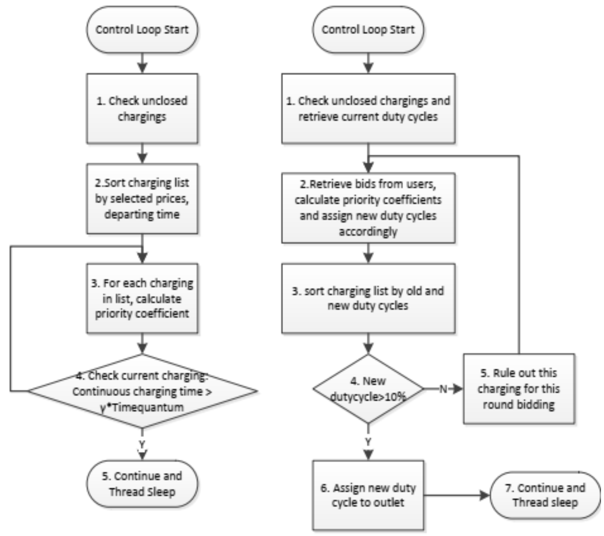

Figure 4: Simplified Level I and Level II Algorithm

For level I EVSE, after each control loop starts, algorithm will select active charging sessions for current EVSE from database, and sort them by their accepted prices and departure time. Only the charging sessions, whose prices agree with user price preferences, can be retrieved. It is assumed that EV drivers, with higher accepted prices and earlier departing time, are in more urgent need for energy and will be given higher priorities than others. To guarantee the energy assigned among users in each time quantum is proportional to their priorities, algorithm calculates priority coefficient □ *i* and the continuous charging time Ti in each control loop. The algorithm will switch from this charging session to a lower one from the charging session list if the present charging session has used up all of its allotted charging time in the current time quantum. Priority coefficients and the associated duty cycle are computed in two steps for level II EVSE. If the duty cycle estimated is less than 10% or the user accepted price is less than the current pricing, the charging session will be temporarily disabled in the first phase. Subsequently, the algorithm will distribute the power source among the remaining charging sessions based on their priority coefficient, after eliminating the unqualified ones. If the current

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falls below the threshold or the scheduled deadline is reached, the charging sessions will end.

4. RESULTS AND DISCUSSION

Information on design considerations, derived values, and parameters for MDIBC simulation are provided in this section. The observations made during the simulation of the MDIBC using the specs are covered in this section.

Table 3: MDIBC Specifications

Parameter	Values
Input voltage, Vin	200 V
Output voltage, Vo	400 V
Output power, Po	10 kW
Switching frequency, FSW	20 kHz
Inductor current ripple, ΔiL	25% of Io
Capacitor voltage ripple, ΔVo	4% of Vo
Number of phases, n	2
Number of parallel devices per phase, p	2

4.1 Voltage at the Open Loop Output

The DC link voltage is displayed in *figure 4*. Up to 650 V of overshoot has been seen, and the system stabilises at 400 V after 5 milliseconds

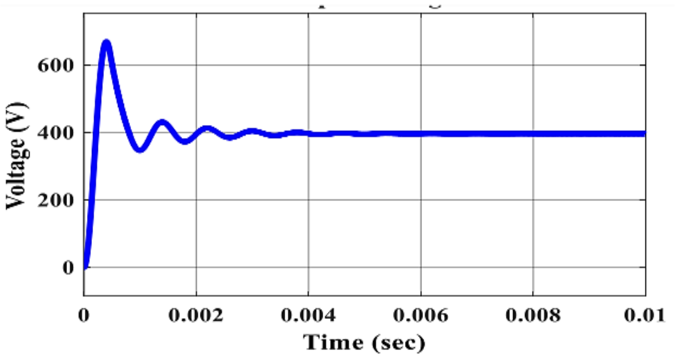

Figure 4: Voltage in the open loop at the DC link

4.2 Inductor Current in an Open Loop

The input inductor's current is shown in *figure 5* for comparison. The current is shown to overshoot up to 125 A before stabilising at 25 A after 5 milliseconds.

We develop and simulate the model in MATLAB, and we give the results of the proposed framework in this part. A Poisson circulation is utilized in the simulation to mimic the EVs appearance stream variety.

The number of charging stations that are available as well as the chance that EVs may hinder traffic due to shifting service rates. As shown in *figure 6 and 7*, in *figure 6* expanding the help pace of MLCI prompts an expansion in the likelihood of impeding as well as the other way around. In *figure 6* expanding the quantity of charging focuses the hindering likelihood are expanded.

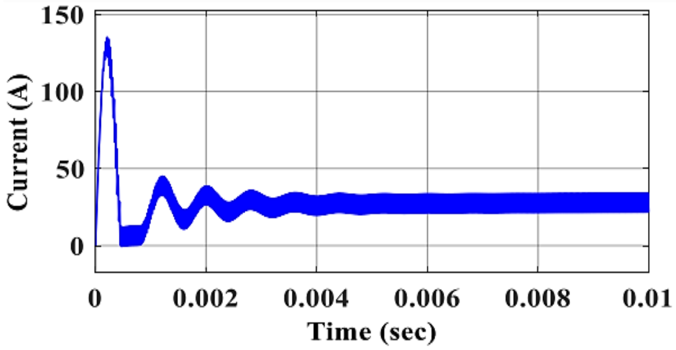

Figure 5: Waveform of the open loop inductor current

Figure 6: EVs Blocking Probability of Multi-level Charging framework

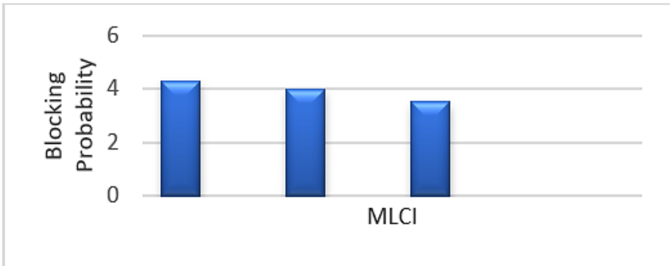

Figure 7: Blocking Probability of Varying Number of chargers

Table 4 compares multilevel charging facilities with existing charging stations (including battery swapping, off-board, and on-board stations). The on- board charging station has low cost and complexity but it has low safety and high traffic. The off-board charging station has more limitation, in battery swapping charging station has low cost and traffic but the complexity is very high. From the comparison we clearly conclude that the proposed several levels of charging has high safety, low traffic, low cost and the low complexity compared to the On-board off-board and battery swapping charging station. In table 4 a represents low, b represents high, ab represents medium and ba represents less. We do sensitivity analysis on the charging vehicle flow. When the charging vehicle flow increases by 5%, the total construction cost of the charging station will increase by 8%. When the charging vehicle flow decreases by 5%, the total construction cost of the charging station will decrease by 4%. Therefore, the charging vehicle flow is not a sensitive factor to the cost.

Table 4: Comparison of proposed with Existing model

Charging station	Safety	Traffic	cost	complexity	Demand, KW	Charging hours
On-board	a	b	a	a	9.7-1.7	1.5-2
Off- board	ab	b	b	b	6.6	2.5 to 3
Battery swapping	ba	a	ab	b	3.6	Up to 4
Multi- Level	b	a	a	a	9.6	3.4

This province is engulfed in an incredible mobility revolution that aims to double the number of electric vehicles and electric vehicle charging stations (EVCS) while also significantly expanding the use of renewable energy sources in the electrical grid. A maximum load demand of 270 kW is observed during the early morning hours of 9:00 to 10:00 h and again during the early evening hours of 21:00 to 22:00 h, based on the results of the modelling of these vehicles' electricity use in EVCS. The examination of generating resources demonstrated the suitability of wind and solar PV, with an average wind speed of 3.6 m/s at 18 m and an average solar daily irradiation of 5 kWh/m2/day, respectively. Batteries, a diesel generator, and a grid link were considered as backup solutions

5. CONCLUSION

This work designs and simulates the MDIBC for an electric Vehicle application. The inverter and drive train serve as the MDIBC's load. It is discovered that inductor ripple is twice as high as switching frequency. The successful multilevel charging station framework strategy for EVs was created in this research. The infrastructure for multi-level charging stations has a distinctive design that has been discussed. The Reconfigurable Converter Topologies is integrated with the created design. The suggested converter demonstrated the stability of the system, and an estimate of costs for the new multi-level charging station infrastructure was done. Additionally, the designed structure's simulated analysis is examined, and important results analysis has also been done. As more vehicles may fit in the space, The suggested converter-based charging station can greatly increase space-freedom and minimise traffic. Multi-level vehicle charging systems can provide a dependable charging option for locations with medium to high daily foot traffic depending on their size, capacity, and design.

Author Contributions:
The authors confirm contribution to the paper as follows: Study conception and design, Data collection, Analysis and interpretation of results and Draft manuscript preparation by Subiramoniyan Seevanthaperumalpillai.

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Conflicts of Interest:
No financial or interpersonal conflicts have been reported by the authors that would have affected the study's findings.

Human and Animal Related Study:
This research did not contain any studies involving animal or human participants, nor did it take place on any private or protected areas

- **Ethical Approval**

Compliance with Ethical Standards.

- **Informed Consent**

Informed consent was obtained from all individual participants included in the study.

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