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# Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations

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**ABSTRACT:** The swift proliferation of electric vehicles (EVs) has necessitated dependable, efficient, and ecological charging options. DC–DC converter-enabled voltage balancers have become vital components in EV charging infrastructure, significantly improving battery performance and optimizing charging efficiency. This study assesses the influence of these converters on the health of EV batteries and charging efficiency, especially in rapid charging conditions. This research utilizes a mixed-methods approach, integrating primary data from structured surveys of 80 respondents with secondary literature, and incorporates quantitative and qualitative analysis through tools such as SPSS 22.0. The statistical analysis indicates substantial relationships among DC–DC converter efficiency, voltage balancer performance, and their impact on battery health and charging effectiveness. Regression study indicates that roughly 31.7% and 32.5% of the variance in battery health and charging efficiency may be ascribed to converter efficiency and balancer performance, respectively. The findings demonstrate that enhanced voltage management and balanced energy transfer substantially decrease energy losses, enhance safety, and prolong battery lifespan. The findings validate that enhanced voltage balancer efficiency and DC–DC converter operation are crucial for the progression of high-performance electric vehicle charging infrastructure. The paper continues by highlighting the capacity of these technologies to facilitate widespread electric vehicle adoption, particularly in metropolitan regions with significant demand for rapid charging. This research provides significant insights for stakeholders in power electronics, electric vehicle design, and smart grid integration.

**KEYWORDS:** Electric Vehicles, DC–DC Converters, Voltage Balancers, Battery Health, Charging Efficiency, Fast-Charging Infrastructure, Energy Management

## I. INTRODUCTION

### Overview of Electric Vehicle (EV) Adoption and Charging Infrastructure

The worldwide initiative for sustainable mobility has positioned electric vehicles (EVs) as central to endeavors aimed at decreasing greenhouse gas emissions and reducing reliance on fossil fuels. This transition is especially important in the transportation sector, which has historically been a substantial source of carbon emissions. Many nations have established lofty objectives for electric vehicle adoption, enacting deliberate policies to promote the shift towards sustainable transportation. These encompass subsidies, tax incentives, and the establishment of extensive charging infrastructure networks. Nonetheless, despite these measures, the adoption rate of electric vehicles remains inconsistent throughout various regions due to diverse socio-economic and infrastructural reasons (Wangchuk & Dema, 2024).

A significant obstacle is the restricted access to public fast chargers, particularly in rural or poor areas. Furthermore, the substantial initial expense of electric vehicles relative to conventional internal combustion engine vehicles is a financial obstacle for numerous prospective consumers. Range concern, stemming from an inadequate number of charging stations, persists in undermining consumer confidence. Moreover, ambiguity around battery longevity and challenges associated with end-of-life battery recycling further complicate the move. These issues combined underscore the essential need of charging infrastructure in facilitating effective and extensive electric vehicle deployment (Das & Bhat, 2022) (H. R. Vidyashree, 2024).

### Principal Obstacles to Electric Vehicle Adoption

Numerous enduring challenges persistently obstruct the seamless incorporation of electric vehicles into conventional transportation. Included in this list are:

- Inadequate charging infrastructure, especially the deficiency of public and rapid-charging stations.
- The elevated initial acquisition costs of electric cars (EVs) persistently exceed those of traditional automobiles.
- Range anxiety arises from drivers' apprehension of becoming trapped due to insufficient nearby charging stations.
- Apprehensions over battery lifespan and the intricacies associated with battery recycling or repurposing.
- Overcoming these obstacles is crucial to expedite the transition to sustainable electric mobility.

Significance of Energy Efficiency and Voltage Regulation in Electric Vehicle Charging  
The increase in electric vehicles and the associated rise in energy usage have made energy efficiency in charging stations a significant issue. Inefficient charging methods lead to energy losses, elevated operational expenses, and significant strain on the electrical infrastructure. This is especially important when the installation of fast-charging stations in urban areas increases, facilitating the concurrent charging of numerous vehicles.

Voltage management is vital for the efficacy and safety of electric vehicle charging infrastructure. Effective voltage regulation guarantees power quality, mitigates grid instability, and safeguards delicate electrical components from harm. Inadequate voltage regulation may lead to voltage sags, harmonic distortions, and interruptions that adversely affect the performance and dependability of charging stations. Moreover, energy-efficient and effectively managed charging infrastructure is more compatible with the integration of renewable energy sources like solar and wind, harmonizing with overarching sustainability objectives (Dutta & Bauman, 2024).

### Development of Voltage Balancers Utilizing DC–DC Converters

Recent improvements in power electronics have resulted in the emergence of DC–DC converter-enabled voltage balancers, which are revolutionizing contemporary EV charging infrastructure. These converters are essential for improving the performance, safety, and efficiency of electric vehicle chargers, especially in rapid and ultra-rapid charging scenarios. They fulfill two major purposes. Initially, they enhance energy transfer efficiency by directly converting the input DC voltage to align with the requisite battery voltage, hence decreasing energy losses during the process. Secondly, they provide active voltage balancing across battery cells, guaranteeing that no individual cell is overcharged or undercharged—a condition essential for prolonging battery lifespan and preserving optimal performance.

DC–DC converters provide numerous benefits compared to conventional AC-based charging solutions. They facilitate compact and lightweight charger designs by removing cumbersome components like transformers. Their high-frequency functioning enhances thermal management and diminishes the dimensions of heat sinks and cooling systems. Furthermore, they improve safety by reducing significant voltage differentials and current surges during the charging procedure. These attributes render them exceptionally suitable for urban fast-charging settings where efficiency, safety, and dependability are critical (Velasquez et al., 2024).

## II. OBJECTIVES

- To examine the relationship between DC–DC converter efficiency and voltage balancer performance in EV charging stations.
- To evaluate the impact of DC–DC converter-enabled voltage balancers on battery health and charging efficiency.
- To identify statistical significance and practical implications for the implementation of advanced charging infrastructure.



### III. LITERATURE REVIEW

(Yehia et al., 2024) Energy storage systems are essential components of microgrids, facilitating their independent functioning. Consequently, extensive study has concentrated on enhancing their longevity and operational efficacy. A significant concern is the maintenance of connected energy storage units (ESUs) at an equivalent state of charge (SoC). Droop control methodologies have been formulated in centralized, decentralized, and distributed approaches. This research introduces an innovative IoT-based droop control capable of achieving State of Charge (SoC) balancing both within a single microgrid and across many microgrids. The proposed architecture enhances dependability and flexibility, facilitating system expansion, reconfiguration, or upgrades, hence simplifying plug-and-play functionality. The proposed hierarchical control and communication architecture based on IoT is introduced. The proposed SoC balancing technique and its integration with IoT architecture are shown. The proposed technique's scalability, adaptiveness, and robustness are confirmed by 24-hour simulations across several scenarios, including the operation of microgrids or energy storage units with differing capacities and during communication failures. The IoT value chain of the proposed method is experimentally tested using a physical laboratory microgrid that employs the HTTP protocol for data transmission via the ThingSpeak IoT-cloud service.

(Catalan et al., 2023) The growing adoption of offshore wind power generation fosters the advancement of wind turbines for high-power applications. The advancement of high-capacity wind turbines surely presents new technical hurdles. This article provides a thorough examination of high-power wind energy conversion systems (WECS), focusing on critical technical features such as topologies, stability, reliability, and auxiliary service capabilities, while also exploring significant problems and potential solutions. A overview and discussion of the several topologies of power converters utilized in high-power wind turbines are presented. The various semiconductor technologies, including recent wide bandgap devices, and their prospective contributions to offshore high-power converters are examined. The possible stability difficulties of high-power wind energy conversion systems are examined and analyzed. The stabilizing control strategies are also examined. The discussion encompasses the reliability concerns and improvement tactics of high-power Wind Energy Conversion Systems (WECS), including condition monitoring, active thermal control strategies, and fault-tolerant operational methods. Furthermore, the auxiliary service capabilities of high-power Wind Energy Conversion Systems, encompassing frequency-active power management and voltage-reactive power control, are examined. This article discusses future tendencies and proposed solutions.

(Qi et al., 2024) The magnetic linked converter is crucial in the power electronics sector owing to its controllability, high power transfer efficiency, and capability for galvanic isolation. The characteristics of the magnetic linked converter render it a significant contender for an efficient interface for the integration of renewable energy into the conventional power grid, applications in more electric aircraft, and the deployment of electric vehicle charging, among others. The conventional controller for the magnetic linked converter employs a linear control mechanism, which fails to provide seamless bidirectional power transfer and enough decoupling, particularly in electric vehicle charging applications. In the most adverse scenario, the conventional controllers may become completely saturated, leading to significant systemic imbalances. Recently, improved control decision-making has been implemented in magnetic linked converter technology for electric vehicle charging applications. The magnetic linked converter technology for electric car charging applications offers enhanced control flexibility, enabling the simultaneous supply of numerous loads through soft-switching capabilities, galvanic isolation, and high-density power transfer. Concerning control approaches, several sophisticated controls have been developed and proposed for the magnetic linked converter to enable strong voltage regulation, seamless bidirectional power routing, and a high degree of decoupling to prevent control interactions to date. Several review studies have examined converter topology, control, and power management for magnetic-linked power converters, focusing on future renewable energy integration into the traditional power grid, applications in more electric aircraft, and electric vehicle charging implementation in the literature. Nevertheless, a comprehensive examination of magnetic-linked power converter topologies, controls, and power management in these applications remains constrained by the diversity of power electronic interfaces with suitable controls and power management. This study provides a thorough review and a detailed evaluation of several magnetic-linked power electronic interfaces, including their controls and power management for upcoming applications.

#### IV. RESEARCH METHODOLOGY

This chapter discusses the study's methods and measurements, as well as ethical concerns, data collection, and analysis. In the academic sense, research is a scholarly Endeavour. It has been said by researchers that research involves outlining and redefining problems, formulating hypotheses about potential solutions, collecting data, drawing conclusions, and then testing those conclusions to see if they are in line with the hypotheses that were developed.

##### Research Design

A study design is used to determine which approach is most appropriate for a certain collection of research objectives and factors. The research questions posed at the beginning of the project can be used to establish a systematic plan for data collection and analysis. Using a descriptive research design, this paper aims to A study of the Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations. There are many ways to conduct a descriptive study, including qualitative and quantitative ones. Researchers used both quantitative and qualitative methodologies in this study. It is a mixed-approach strategy. As part of the research process, it is essential to define the investigation's goals and objectives, as well as gather and analyze data from participants. The focus of this research is on the Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations.

##### Research Approach

The technique of a study is the most important part of the project. Choosing the right research strategy is dependent on the objectives of the A study of the Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations survey research techniques. The data will be collected through the use of questionnaires already developed. When participating in the survey it is possible for respondents to choose between structured and free questions.

##### Research variables

Variables are characteristics that are unique to each individual subject being studied. As an idea, it's one that can be measured. We use the term "variable" to describe between The Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations “Independent Variable” The researcher has direct control over this variable, which has an effect on the dependent variable. The independent variable in this research is Voltage Balancer Performance and DC–DC Converter Efficiency.

##### Dependent Variable

To put it another way, the dependent variable is the one you're testing or measuring in an experiment. This study's dependent variable is Battery Health and Charging Efficiency.

##### Sample and sampling technique

Sampling is the process of selecting a subset of a larger group in order to make generalizations about Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations. Probability sampling and non-probability sampling are the two types of sampling procedures. It is termed "probability sampling" because it involves drawing a random sample from a target EV customers at random. This type of sampling relies less on randomness when selecting a representative sample group. Deliberate sampling was required in order to perform a qualitative investigation into the Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations

##### Source of the Samples

A primary data set has been utilized in this study's analysis. The following list provides a quick overview:

##### Primary Data

The primary sources of primary data are all EV customers hence, the need for a web-based application (a form). Questionnaires have been used to collect primary data for this research project.

**Secondary data**

A secondary data set is a compilation of information derived from a primary set. There are a lot of records in this category. Secondary data can be found in a variety of places, including books and journals, the internet, and official government records.

**Methods and Tools used**

The data was collected through a survey. Surveys are common among many methods of collecting information from EV customers. All surveys characterize or explain the characteristics and attitudes of the EV customers through the use of a sample. the Effect of DC–DC Converter-Enabled Voltage Balancers on Battery Health and Charging Efficiency in EV Stations was assessed using a checklist. And here we have taken 80 respondents and those have been obtained through survey of many offices.

**Area of study**

The study would be conducted mainly in the Bhopal.

**Statistical Analysis****Data Analysis**

Using raw data for data analysis, conclusions can be derived. A preliminary data analysis is necessary before beginning the data preparation process, which includes data entering, editing, and coding. Using software to analyze data quickly and accurately is essential for it to be helpful. The study's data was entered into a spreadsheet for analysis. Each respondent's responses were assigned an integer value before being placed into a spreadsheet. Using SPSS, we were able to analyze and model our data.

The data in this study was analyzed using SPSS 22.0, a statistical software package. Analytical procedures such as ANOVA and percentage approaches were used to investigate the data that was regarded as the most significant. In order to have a clearer understanding of the study's most critical elements, percentage analysis was used. Comparing and analyzing data using percentages is a powerful technique. This is one of the simplest ways to get your point through to the audience you're targeting. When data is gathered, an overall picture of the situation can be painted. Use of graphs can improve the appeal of percentage analyses.

**V. RESULT****Table 1: Age**

Age		
	Frequency	Percent
Under 18 year	18	22.5
18-25 year	25	31.3
26-35 year	10	12.5
35-45 year	15	18.8
Above 46 year	12	15.0
Total	80	100.0

The age distribution of participants indicates that the predominant group is aged 18–25, accounting for 31.3% of the entire sample. Subsequently, participants under 18 years of age represent 22.5%. The age group of 35–45 years constitutes 18.8%, and individuals above 46 years account for 15% of the respondents. The 26–35 year age group comprises the smallest proportion, contributing at 12.5%. The data reveals a predominantly young participant base, with more than half (53.8%) aged 25 years or younger, indicating a demographic skew towards youth.

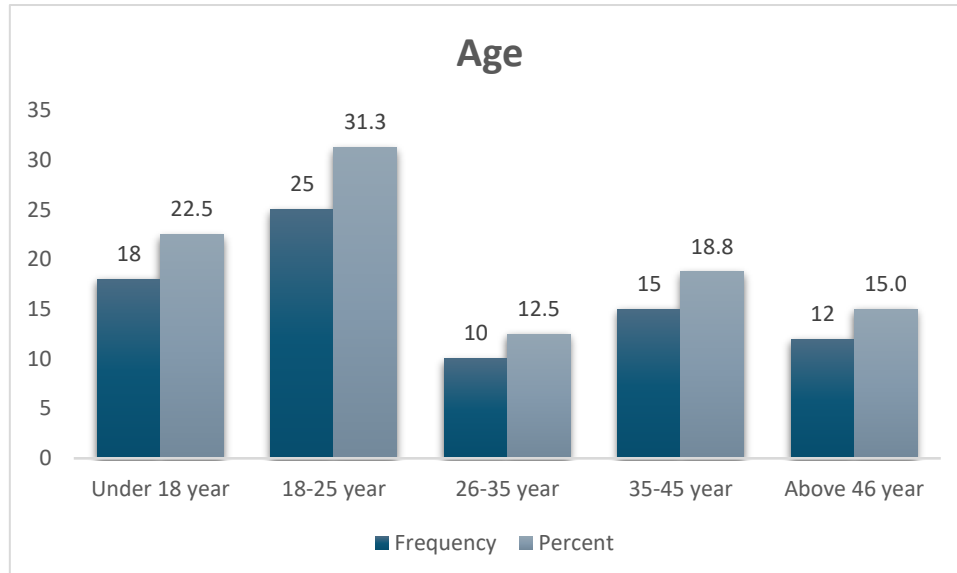


Figure 1: Age

Table 2: Gender

Gender		
	Frequency	Percent
Male	36	45.0
Female	44	55.0
Total	80	100.0

The gender distribution of the participants indicates a marginally greater representation of girls, comprising 55% of the entire sample, in contrast to males at 45%. This suggests a very equitable involvement between genders, with a minor female majority. The sample comprises both genders in almost equal numbers, hence augmenting the data's representativeness across gender demographics.

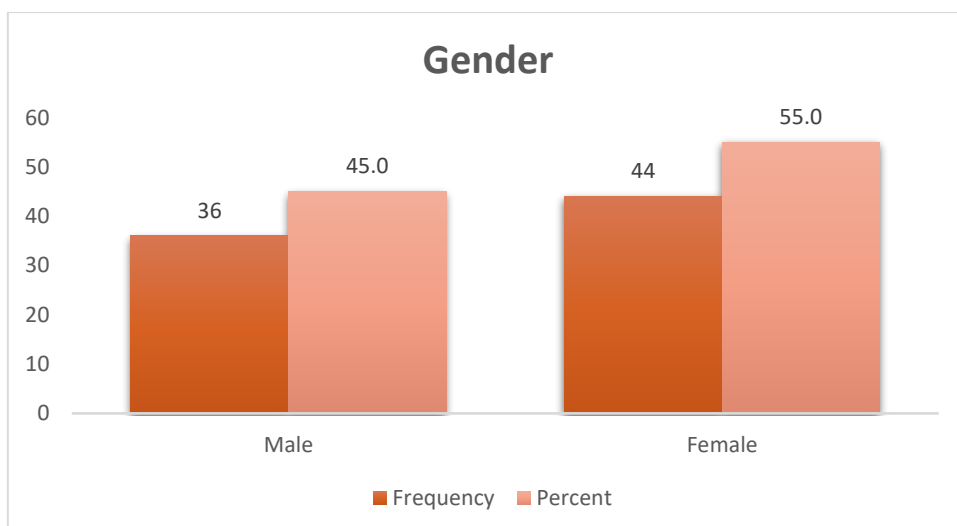
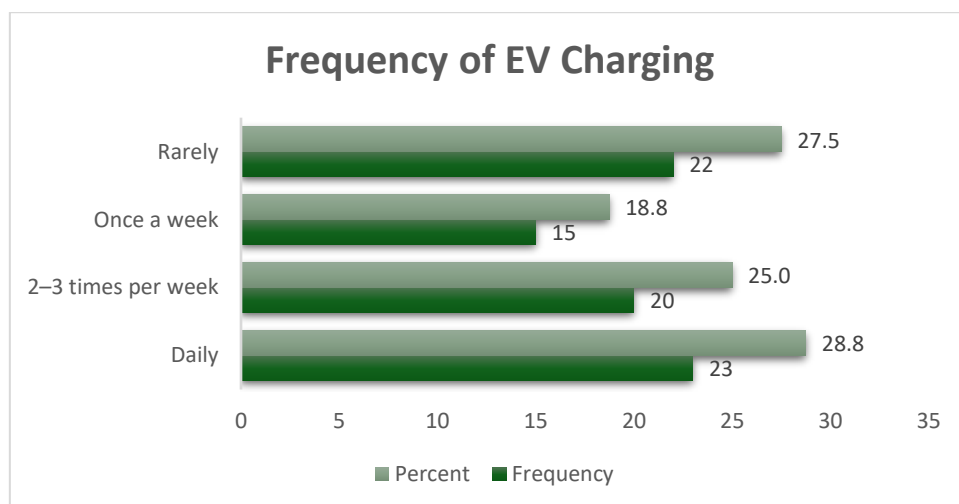


Figure 2: Gender

**Table 3: Frequency of EV charging**

Frequency of EV Charging:		
	Frequency	Percent
Daily	23	28.8
2–3 times per week	20	25.0
Once a week	15	18.8
Rarely	22	27.5
Total	80	100.0

The statistics about EV charging frequency reveals that the largest percentage of respondents (28.8%) charge their electric vehicles everyday, closely followed by those who infrequently charge (27.5%). Twenty-five percent of individuals report charging 2 to 3 times per week, whilst 18.8% charge only once weekly. This distribution indicates varied charging behaviors among users, with a considerable percentage adhering to regular charging practices, while a major segment charges seldom, either due to reduced usage or availability of alternative transportation options.



**Figure 3: Frequency of EV charging**

#### Hypothesis 1:

There is a significant correlation between DC–DC Converter Efficiency and Voltage Balancer Performance.

**Table 4: Correlation on hypothesis 1**

Correlations			
		DC–DC Converter Efficiency	Voltage Balancer Performance
DC–DC Converter Efficiency	Pearson Correlation	1	.577**
	Sig. (2-tailed)		.000
	N	80	80
Voltage Balancer Performance	Pearson Correlation	.577**	1
	Sig. (2-tailed)	.000	
	N	80	80

\*\*. Correlation is significant at the 0.01 level (2-tailed).



The correlation table shows a statistically significant positive relationship between DC–DC Converter Efficiency and Voltage Balancer Performance, with a Pearson correlation coefficient of 0.577. This indicates a moderate positive correlation, meaning that improvements in one variable are associated with improvements in the other. The significance value ( $p = .000$ ) confirms that this relationship is highly significant at the 0.01 level (2-tailed), indicating strong evidence that the observed correlation is not due to chance. With a sample size of 80, the data supports a meaningful association between these two technical components in the context of EV charging systems.

### Hypothesis 2:

There is a significant impact of DC–DC Converter Efficiency on Battery Health and Charging Efficiency.

**Table 5: Regression on hypothesis 2**

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.563 <sup>a</sup>	.317	.309	.748
a. Predictors: (Constant), DC–DC Converter Efficiency				

The model summary reveals a moderate positive correlation between the predictor variable (DC–DC Converter Efficiency) and the dependent variable. The correlation coefficient (R) is 0.563, indicating a moderate linear relationship. The R Square value is 0.317, indicating that roughly 31.7% of the variance in the dependent variable is accounted for by the efficiency of the DC–DC converter. The Adjusted R Square, which considers the number of predictors and sample size, is marginally lower at 0.309, so affirming the model's moderate explanatory capacity. The standard error of the estimate is 0.748, indicating the mean deviation of the observed data from the regression line. The model exhibits a significant albeit not robust predictive correlation.

ANOVA <sup>a</sup>						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.280	1	20.280	36.276	.000 <sup>b</sup>
	Residual	43.607	78	.559		
	Total	63.887	79			
a. Dependent Variable: Battery Health and Charging Efficiency						
b. Predictors: (Constant), DC–DC Converter Efficiency						

The ANOVA table evaluates the overall significance of the regression model. The regression sum of squares is 20.280, the residual sum of squares is 43.607, resulting in a total sum of squares of 63.887. The model is statistically significant at the 0.05 level, with an F-value of 36.276 and a p-value of .000. This suggests that the efficiency of the DC–DC converter is a significant predictor of fluctuations in battery health and charging efficiency. The regression model demonstrates a strong fit for the data, and the independent variable significantly influences the dependent variable.

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.249	.377		3.316	.001
	DC–DC Converter Efficiency	.580	.096	.563	6.023	.000
a. Dependent Variable: Battery Health and Charging Efficiency						

The coefficients table indicates that DC–DC Converter Efficiency has a statistically significant positive impact on Battery Health and Charging Efficiency. The unstandardized coefficient (B) for DC–DC Converter Efficiency is 0.580, signifying that for each unit improvement in converter efficiency, battery health and charging efficiency rise by

0.580 units, assuming all other factors remain constant. The standardized coefficient (Beta) of 0.563 indicates a moderate positive effect in standardized terms. The t-value of 6.023 and a significance level of .000 ( $p < 0.05$ ) unequivocally affirm that this effect is statistically significant. The constant value of 1.249 signifies the anticipated state of battery health and charging efficiency under conditions of zero converter efficiency. The model indicates that enhancements in DC–DC converter efficiency markedly improve battery health and charging efficacy.

### Hypothesis 3:

There is a significant impact of Voltage Balancer Performance on Battery Health and Charging Efficiency.

**Table 6: Regression on hypothesis 3**

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.570 <sup>a</sup>	.325	.316	.744
a. Predictors: (Constant), Voltage Balancer Performance				

The model summary reveals a moderate positive association between Voltage Balancer Performance and the dependent variable. The correlation value (R) is 0.570, indicating a moderate linear association. The R Square score of 0.325 indicates that roughly 32.5% of the variance in the dependent variable is elucidated by Voltage Balancer Performance. The Adjusted R Square, marginally reduced to 0.316, accounts for sample size and predictor quantity, hence affirming a reasonable model fit. The standard error of the estimate is 0.744, signifying the mean departure of observed values from expected values. The model indicates that Voltage Balancer Performance exerts a significant although moderate impact on the outcome variable.

ANOVA <sup>a</sup>						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.752	1	20.752	37.524	.000 <sup>b</sup>
	Residual	43.136	78	.553		
	Total	63.887	79			
a. Dependent Variable: Battery Health and Charging Efficiency						
b. Predictors: (Constant), Voltage Balancer Performance						

The ANOVA table indicates that the regression model utilizing Voltage Balancer Performance as a predictor is statistically significant. The regression sum of squares is 20.752, the residual sum of squares is 43.136, resulting in a total variance of 63.887. The model exhibits strong significance at the 0.05 level, evidenced by an F-value of 37.524 and a p-value of .000. This suggests that Voltage Balancer Performance substantially accounts for the disparity in Battery Health and Charging Efficiency. The predictor significantly improves the model's capacity to elucidate variations in the dependent variable.

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.336	.357		3.741	.000
	Voltage Balancer Performance	.575	.094	.570	6.126	.000
a. Dependent Variable: Battery Health and Charging Efficiency						

The coefficients table demonstrates that Voltage Balancer Performance exerts a statistically significant and favorable influence on Battery Health and Charging Efficiency. The unstandardized coefficient (B) is 0.575, indicating that for each one-unit increase in Voltage Balancer Performance, the Battery Health and Charging Efficiency score rises by 0.575 units, provided all other variables are held constant. The standardized coefficient (Beta) is 0.570, indicating a moderate positive impact in standardized terms. The t-value of 6.126 and the p-value of 0.000 indicate that this link is statistically significant. The fixed value of 1.336 denotes the anticipated value of the dependent variable when Voltage Balancer Performance is null. The results indicate that enhanced voltage balancer performance is significantly correlated with advancements in battery health and charging efficiency.

### Discussion

The transition of the global transportation sector to electric vehicles is both essential and unavoidable. The extensive adoption of electric vehicles is significantly contingent upon the efficiency, dependability, and safety of their charging infrastructure. This paper examines the evolving function of DC–DC converter-based voltage balancers in enhancing electric vehicle charging systems. The discourse centers on the impact of these components on two important outcomes—battery longevity and charging efficacy.

DC–DC converters are essential for adjusting voltage levels as needed by the EV battery system. The research demonstrates a robust positive association between the efficacy of these converters and the functionality of voltage balancers. A Pearson correlation coefficient of 0.577 ( $p < 0.01$ ) indicates that increased converter efficiency substantially enhances voltage control. Effective voltage balancing guarantees that individual cells in a battery pack are neither overcharged nor undercharged, thus enhancing battery longevity and ensuring consistent performance.

The regression results substantiate the notion that both DC–DC converter efficiency and voltage balancer performance significantly impact battery health and charging efficiency. Approximately 31.7% and 32.5% of the variance in the dependent variable (battery health and charging efficiency) is elucidated by the corresponding independent factors. This demonstrates a strong and roughly equivalent contribution from both technological features.

Furthermore, sophisticated converter systems enhance compact charger design, improve thermal management, and minimize voltage differentials during high-power charging. These features are vital in metropolitan settings where fast-charging facilities are necessary to satisfy increasing demand. Improved performance not only lowers operational expenses but also enhances grid stability when combined with renewable sources.

The integration of DC–DC converter-enabled voltage balancers improves the sustainability and efficiency of electric vehicle charging systems. The statistical results highlight the significance of technology enhancement in propelling future developments in EV infrastructure.

### VI. CONCLUSION

This study highlights the crucial importance of DC–DC converter-enabled voltage balancers in enhancing the performance and reliability of electric vehicle charging stations. Empirical study of primary data and statistical modeling demonstrates a definitive correlation between the efficiency of these converters and enhancements in battery health and charging efficiency. The Pearson correlation and regression results demonstrate statistically significant connections, providing robust proof that improved voltage balancer performance and converter efficiency result in substantial advantages for electric vehicle operations.

The results indicate that more than 30% of the variance in battery performance indicators can be directly ascribed to these two factors. These discoveries have practical implications: extended battery longevity, reduced energy wastage, enhanced safety, and increased user confidence in electric vehicle technology. With the increasing demand for fast-charging, particularly in metropolitan areas, these technologies are crucial for alleviating pressure on electric grids, assuring voltage stability, and preserving overall charging efficiency.

Moreover, the implementation of contemporary power electronic systems, such as DC–DC converters, facilitates the smooth integration of renewable energy sources, enhancing the sustainability of EV infrastructure. By alleviating

voltage sags and current surges, they safeguard delicate components and diminish operational expenses. This establishes the technology as a fundamental component in smart grid architecture and electric mobility advancement.

The study illustrates the effectiveness of integrating DC–DC converter-enabled voltage balancers as a strategic improvement to electric vehicle charging systems. It provides essential data for stakeholders, including politicians and engineers, aimed at developing scalable and future-ready charging networks. By guaranteeing performance optimization and environmental compatibility, these technologies constitute an essential foundation for the global shift towards cleaner, more efficient transportation networks.

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