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Regulating the battery voltage for EV motors using Y Source bidirectional DC-DC converter compared with delta source converter by introducing switched regulators

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Abstract

Aim: The aim of this research is to improve the voltage of a battery in an electric vehicle by recommending Y sourced bidirectional DC-DC converter and compared it with delta sourced bidirectional DC-DC converter based electric vehicle battery system. **Materials and Methods:** The voltage of the battery with Y sourced bidirectional DC-DC converter and delta sourced bidirectional DC-DC converter is examined using 7 samples per group and duty cycles to analyze the battery voltage. **Results:** Based on the findings, it is inferred that the Y sourced bidirectional DC-DC converter has improved overall battery voltage 12.1845 V while the delta sourced bidirectional DC-DC converter has a battery voltage of 10.1826 V. The significance value is determined as 0.76 ($p>0.05$, statistically insignificant) based on SPSS analysis. **Conclusion:** Compared to a delta sourced bidirectional DC-DC converter, Y sourced bidirectional DC-DC converter provides a better battery voltage for the selected data.

Keywords

Novel Y-Source bidirectional DC-DC Converter, Electric Vehicle, delta source, Battery system, Control technique, Power Electronics, Duty cycle.

INTRODUCTION

Nowadays, with the development of science and technology, the DC power supply system develops rapidly. On various occasions, the performance, cost and parameters of DC-DC converters are increasingly demanded. How to design DC-DC converters with smaller size, lower cost and better performance have become (Islam, Shah, and Ali 2021)the subject of power technology research. The traditional Buck/Boost converter has lower voltage gain, poor stability, and its (Sharifabadi et al. 2016) safety and reliability are not high, which limits its development. In order to solve the above problems, many scholars have proposed many improved Z source inverter circuit topologies, such as a switched inductor Z-source inverter (Březina and Jabłoński 2017), trans Z-source inverter (Appleby and

Foulkes 1993), a family of T-source networks, LCCT Z-source, Y-source inverter and so on. Compared with the traditional DC-DC converter, the novel Y-source bidirectional DC-DC converter can greatly reduce the volume, weight and cost of the system when it requires bidirectional power flow. (Sujitha and Krithiga 2019) The main applications of the proposed converter are (Norsworthy 1996) used in Battery chargers, Quadcopters, Solar chargers, Power audio amplifiers.
Based on the literature, about 1978 papers have been published in IEEE and Google scholars are reviewed. At all power levels, a battery charger can allow (Yang et al. 2018)unidirectional or bidirectional power transfer. The vehicle-to-grid (V2G) mode is added to the grid-to-vehicle interface (G2V) by the bidirectional power flow. With a bidirectional power flow, the EVs can be used as the backup generation, supplying energy back to the grid when needed (Han and Acquah 2021). This technology can significantly improve the overall reliability of the distribution grid, because in (Han and Acquah 2021)the event of system failure, peak load demand, or other unexpected scenarios, the EVs can be used as the backup generation, supplying energy back to the grid when needed. With V2G, like with any energy storage system, EV batteries can be used(Han and Acquah 2021; Batarseh and Harb 2017) not just as a backup resource, but also to improve power quality, network reliability, and operational costs. Furthermore, V2G has the potential to reduce long-term investment in new power generation infrastructure(Saponara and Mihet-Popa 2020). The novel bidirectional Y-source DC-DC converter has a unique network structure, which makes its input current continuous and has a strong ability to resist electromagnetic interference, which further enhances the stability of the (Pinto and Valente 2019) output voltage. It can achieve higher voltage gain and keep the voltage stress of electronic equipment at a lower level. In addition, the existence of the DC blocking capacitor avoids the problem of saturation of the coupled inductor core caused by overcurrent.
Previously our team has a rich experience in working on various research projects across multiple disciplines (Venu and Appavu 2021; Gudipaneni et al. 2020; Sivasamy, Venugopal, and Espinoza-González 2020; Sathish et al. 2020; Reddy et al. 2020; Sathish and Karthick 2020; Benin et al. 2020; Nalini, Selvaraj, and Kumar 2020).The majority of extant research, Delta source DC-DC converters are designed to provide reliable backup power for equipment with supply voltages different from the main battery backup system. Delta DC converters complement our systems to produce total site power solutions. The conventional converter for the electric vehicle battery system can have the least to increase the voltage of the battery. The aim of this research is to improve the voltage of a battery in an electric vehicle by recommending Y sourced bidirectional DC-DC converter and compared with delta sourced bidirectional DC-DC converter based electric vehicle battery system by optimizing the duty cycle.

MATERIALS AND METHODS

The research was done in the power Electronics lab, Department of Electrical and Electronics Engineering, Saveetha school of Engineering, Saveetha institute of Medical and Technical sciences. Two topologies have been compared and its sample size has been calculated by using G power software. It was determined that each method has 7 samples and a total number of 14 samples (g power=0.8) (Pascual-trenor 2019). The system is simulated using the MATLAB simulink software (Siano and Jamuna 2020).
Group 1 and 2 sample preparation was done by collecting 7 different voltage values by varying duty cycle from 0.3 to 0.9, here the parameters considered are duty cycle and voltage.

Delta source bidirectional DC-DC converter

The conventional delta sourced bidirectional DC-DC converter for the EV battery system is presented in Fig.1. This system consists of source DC voltage which is connected to the battery with a delta-source (Aharon et al. 2021)bidirectional DC-DC converter. The delta sourced bidirectional DC-DC converter output current is compared with reference duty cycle-based reference current. The error current is processed (Siano and Jamuna 2020;

Singh et al. 2017) by the PI controller. The PI controller is generating the control signal and it is processed with the PWM generator. The PWM generator is generating the pulse for delta sourced bidirectional DC-DC converter to charge the battery.

Y- source bidirectional DC-DC converter

The proposed novel Y-source bidirectional DC-DC converter for the EV battery system is presented in Fig.2. This system consists of source DC voltage which is connected to the battery a Y sourced bidirectional DC-DC converter. The novel Y-source bidirectional DC-DC converter output current is compared (Rafique, Rehman, and Ahmed 2008) with reference duty cycle-based reference current. The error current is processed with the PI controller. The PI controller is generating the control signal and it is processed with the PWM generator. The PWM generator is generating the (Hernandez and Electrical Engineering and Electronics 1983) pulse for Y sourced bidirectional DC-DC converter can charge the battery. Table 1 shows that the proposed Y sourced bidirectional DC-DC converter is able to charge the battery with a higher voltage than the conventional delta sourced bidirectional DC-DC converter. The findings of the suggested scheme have been confirmed by adjusting the duty cycle in the MATLAB/Simulink environment.

A Google Collab open source stage with a center i5, tenth era processor and 8GB RAM is utilized for the proposed method.

Statistical Analysis

Y sourced bidirectional DC-DC converter and delta sourced bidirectional DC-DC converter are statistically analyzed using SPSS software. For example, the independent variable in a voltage converter is its duty cycle from 0.3 to 0.9, while its dependent variable is its battery voltage. Both converters are subjected to two independent group analysis tests to determine the battery voltage of the EV battery system.

RESULTS

Table 1 Simulation results of the Conventional delta source DC-DC converter and proposed Y source bidirectional DC-DCconverter. Table 2 Shows the T-test comparison of Y source bidirectional DC-DC converter and delta source DC-DC converter for mean value, standard deviation value, the standard error of battery voltage. Y source bidirectional DC-DC (Mean value of 12.1845) based converter produces better battery voltage than the delta source DC-DC converter (Mean value of 10.1826). The standard error values for Y source bidirectional DC-DC is (.00249) and for delta source DC-DC is (.00236) which ensures the proposed method's superiority. Table 3 Shows the independent sample test for significance and standard error determination with Y source bidirectional DC-DC and delta source DC-DC converter. Significance value obtained as 0.76 ($p>0.05$), considered to be statistically insignificant with a 95% confidence interval.

Figure 1 Displays the simulink block diagram of the delta source bidirectional DC-DC converter for EV battery system. Figure 2 Displays the simulink block diagram of the Y Source bidirectional DC-DC converter for EV battery system. Figure 3 Displays the output battery voltage and source voltage in Y-Source bidirectional DC-DC converter. Figure 4 Displays the output battery voltage and source voltage in the delta source converter.

Figure 5 Depicts the bar graph analysis on the battery voltage of both Y source bidirectional DC-DC and delta source DC-DC converters. It is inferred that the proposed converter produces better battery voltage compared to the conventional delta source DC-DC converter.

DISCUSSION

From the study, it is evident that the proposed method can achieve higher current gain rather than a delta source converter. Due to its several advantages and adverse effects, the usage is much needed and more economical. The role of the proposed method will play a vital role in transmission and distribution, microgrid concept, renewable resources, etc.

Concerns about carbon dioxide emissions, greenhouse gas emissions, and the rapid depletion of fossil fuels have heightened the need to develop and embrace new eco-friendly, long-term alternatives to internal combustion engine (ICE) cars. As a result, electric vehicles (EVs) have become more common in the previous decade, owing to their low flue gas emissions and reduced dependency on oil. By 2022, it is expected that there will be over 35 million electric vehicles on the road worldwide. However, one major difficulty with control technique EVs is that their widespread use produces considerable problems on the power distribution grid, including power quality degradation, increased line damage, distribution transformer downturn, greater distortion, and higher fault current (Kumar, Vyas, and Datta 2019; Zhou et al. 2019). Integrating local power generation, such as renewable energy sources (RESs), into the EV charging infrastructure is one effective way to mitigate the damage (Longo, Foiadelli, and Yaïci 2019; Thomas and Sandy Thomas 2009; Liu et al. 2015). The battery voltage with delta sourced bidirectional DC-DC converter (Norsworthy 1996) and a control technique Y sourced bidirectional DC-DC converter (Sujitha and Krithiga 2019; Wang and Li 2012) for an electric vehicle battery system is examined and compared. Delta sourced bidirectional DC-DC converter has a lower battery voltage when compared to the Y sourced bidirectional DC-DC converter. It has oppositions such as discontinuous current mode and unidirectional power flow. A controller designed for one direction but performing poorly in the other, bidirectional operation without symmetrical voltage gain resulting in asymmetrical operation, and simultaneous modulated step-up and step-down switches resulting in increased switching losses are just a few of the major drawbacks.
The limitations of renewable resources are the best option for meeting load requirements and protecting the environment from pollution and toxins in today's environment. Installing charging stations near renewable energy farms lowers transmission costs while also improving power quality.
In the future, the proposed inverter preserves the advantages of the impedance source inverter such as high boosting and small shoot through interval.

CONCLUSION

Based on the results the proposed Y sourced bidirectional DC-DC converter has better battery voltage 12.18453 when compared to the conventional delta sourced bidirectional DC-DC converter of 10.1826 for the selected data. Based on the independent T test the significance value is 0.76 ($p > 0.05$) statistically insignificant within the limit of study.

DECLARATION

Conflicts of Interest
No conflict of interest in this manuscript.
Author Contributions
Author S.B was involved in data collection, data analysis and manuscript writing. Author S.B was involved in conceptualization, data validation and critical review of manuscripts.
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Tables and Figures

Table 1. Simulation results of the Conventional delta source DC-DC converter and proposed Y source bidirectional DC-DC converter.

Duty cycle	**Battery Voltage (Volts)**	
	Y sourced bidirectional DC-DC converter	**Delta sour bidirectional DC-DC converter**
0.9	12.1911	10.190
0.8	12.1933	10.191
0.7	12.1831	10.181
0.6	12.1832	10.181
0.5	12.1838	10.179

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0.4	12.183	10.181
0.3	12.1742	10.173

Table 2. Group statistical analysis of novel Y source bidirectional DC-DC and conventional delta source DC-DC converter by taking7 samples per group. The standard error mean for the modified bidirectional DC-DC converter is .00249 and for the conventional delta source DC-DC converter is .00236.

Group Statistics					
	Group	**N**	**Mean**	**Std.Deviation**	**Std.Error Mean**
Battery Voltage	**Y source**	7	12.1845	.00659	.00249
	Delta source	7	10.1826	.00624	.00236

Table 3. Independent sample T-test is performed for the two groups for significance and standard error determination. Since the value of significance is 0.76 (p > 0.05) which is considered to be statistically insignificant.

Independent Samples Test										
Levene's Test For Equality Variances						T-test for Equality of Means		95% Confidence Interval of the 95% Confidence Interval of the Difference	
		F	Sig	t	diff	Sig (2-tailed)	Mean Difference	Std Error Difference	Lower	Upper
BatteryVoltage	Equal Variances assumed	.097	.760	583.764	12	.001	2.00194	.00343	1.99446	2.00941
	Equal Variances not			583.764	11.963	.000	2.00194	.00343	1.99446	2.00941

	assume d									

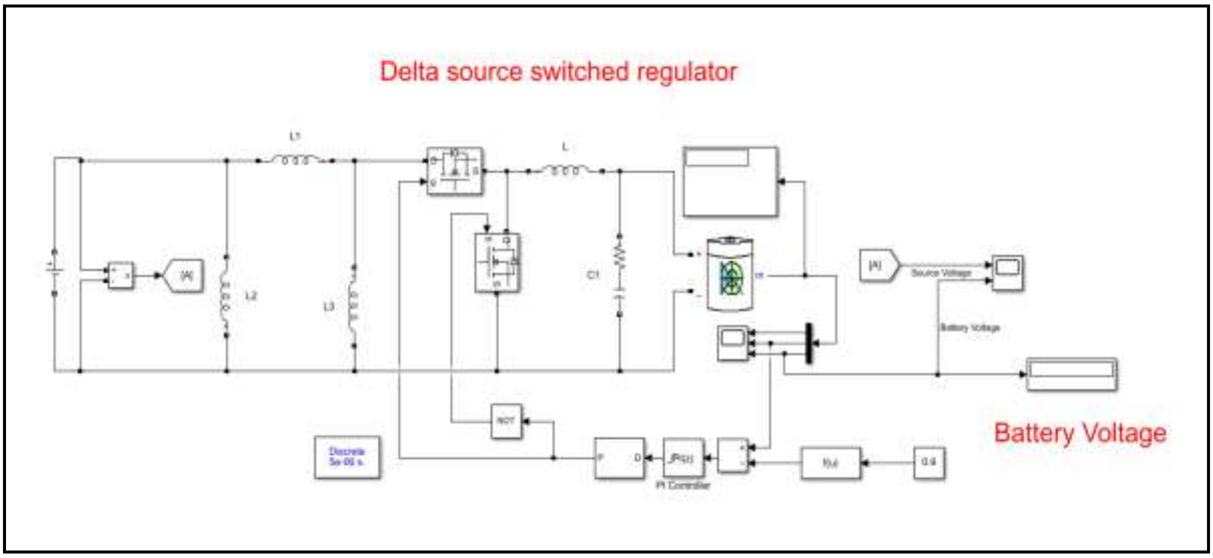

Fig .1. Displays the simulink block diagram of delta sourced bidirectional DC-DC converter for EV battery system.

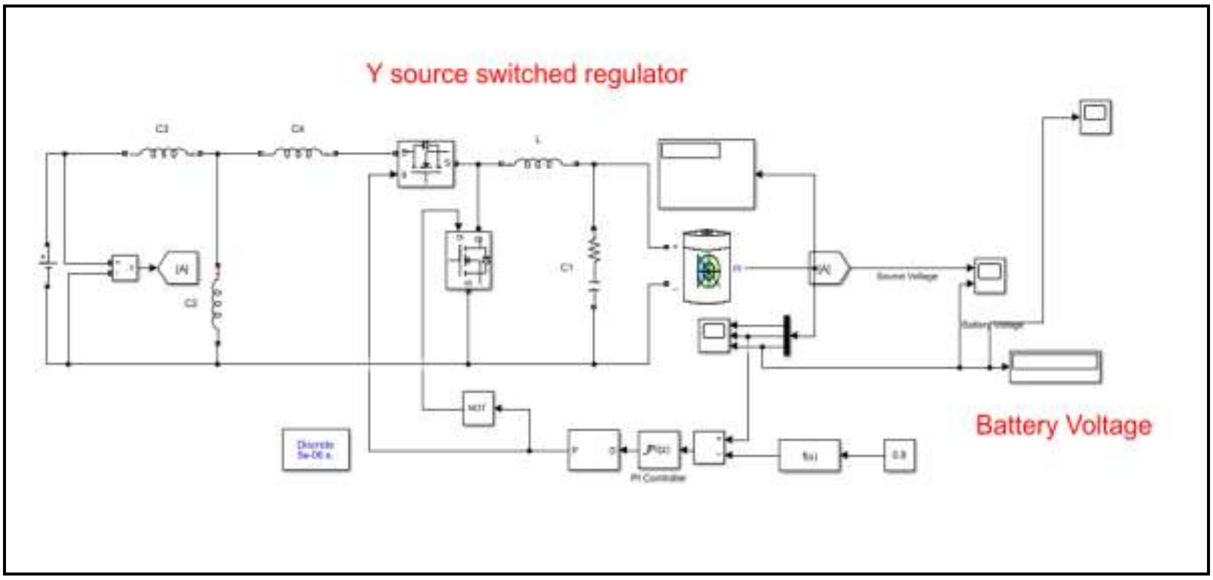

Fig .2. Displays the simulink block diagram of Y source bidirectional DC-DC converter for EV battery system.

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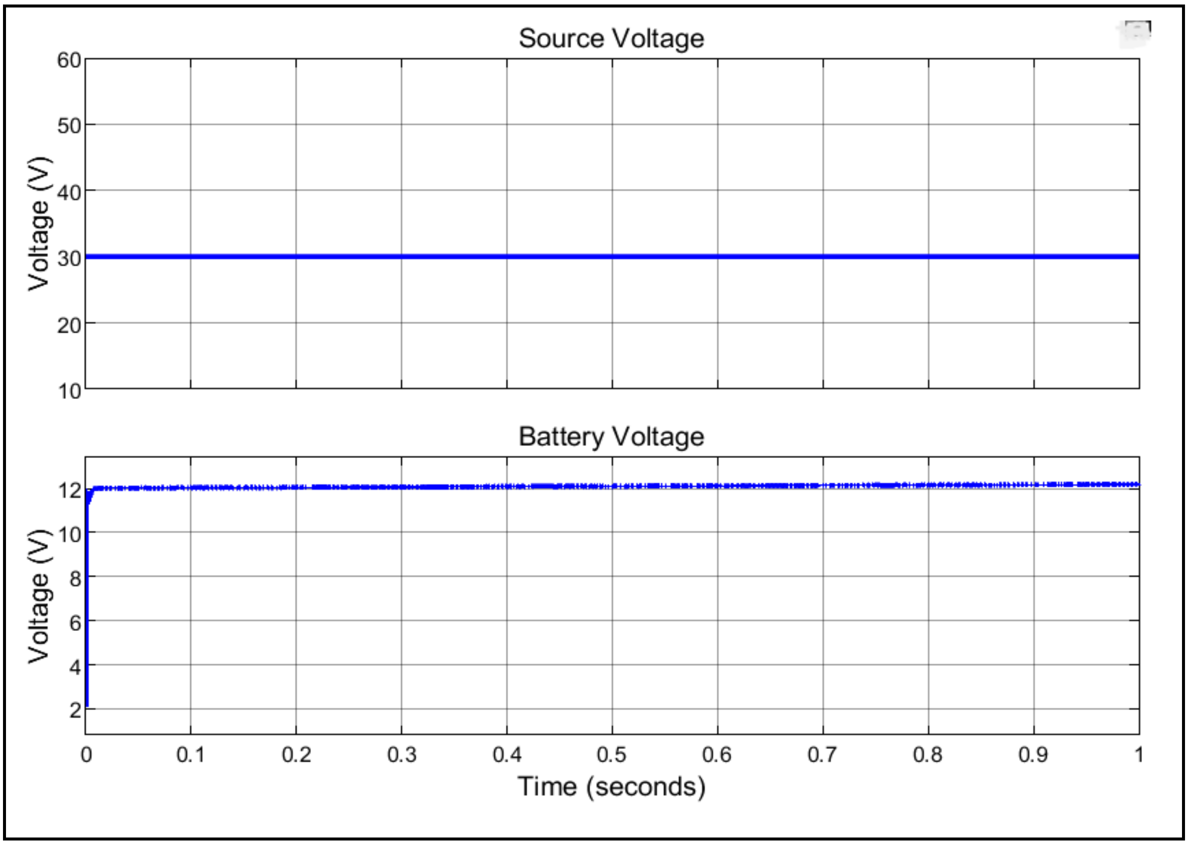

Fig .3. Displays the output battery voltage and source voltage in Y-Source bidirectional DC-DC converter.

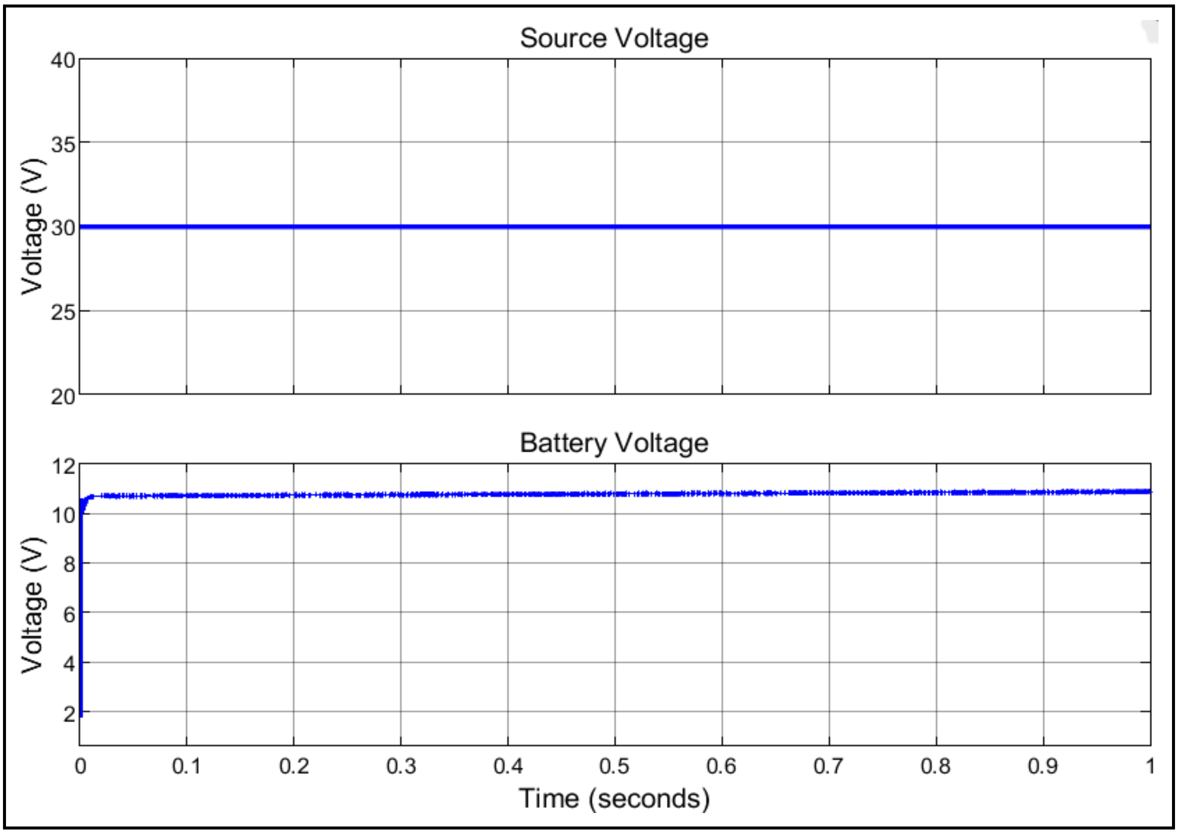

Fig .4. Displays the output battery voltage and source voltage in the delta source converter.

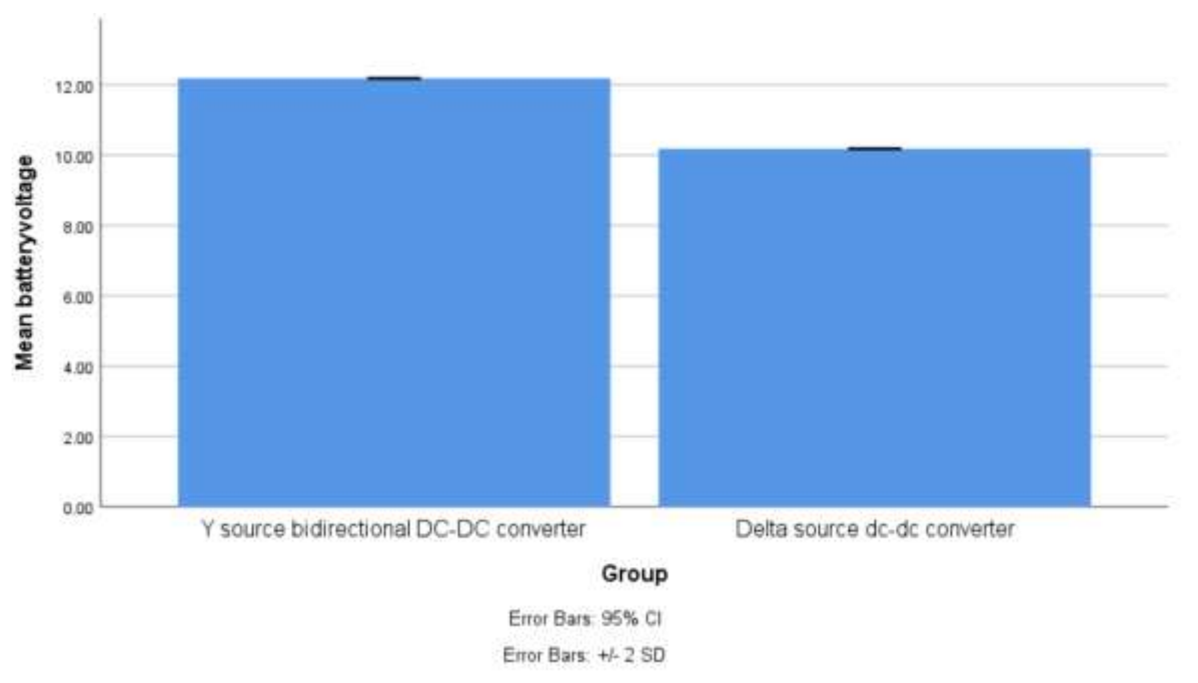

Fig .5. Comparison of conventional delta source DC-DC and modified Y source bidirectional DC-DC converter method in terms of battery voltage. The battery voltage of the modified Y source bidirectional DC-DC converter is 12.1% and for the conventional delta source DC-DC converter is 10.1%, which proves that the proposed converter technique is better than the conventional converter. Device count with ±1SD.