IJITCE

ISSN 2347- 3657

International Journal of Information Technology & Computer Engineering

Email : ijitce.editor@gmail.com or editor@ijitce.com

International Journal of Information Technology & Computer Engineering

ISSN 2347–3657

Volume 12 , Issue 1, Mar 2024

A WIDE RANGE OUTPUT VOLTAGE CHARGER FOR ELECTRICAL VEHICLES

Mr. D. PRAKASA RAO[1], S. SUJATHA SONY[2], P. SUBHA SREYA[3], R. SURYA[4], K. MONIKA LAKSHMI[5], T. SATYA MURALI[6]
[1]Assistant Professor , Dept.of EEE, PRAGATI ENGINEERING COLLEGE
[23456]UG Students,Dept.of EEE, PRAGATI ENGINEERING COLLEGE(Autonomous)

ABSTRACT

In a home, off-board chargers are required to charge low voltage powered electric vehicles (LEVs) as well as high voltage powered electric vehicles (HEVs). Keeping this in view, this work presents the design and control of a single-stage bidirectional electric vehicle (EV) charger with a wide output voltage range from 72 V to 240 V. Moreover, the presented bidirectional EV charger facilitates the user to utilize the vehicle battery to supply the home loads, i.e. vehicle-to-home operation during the unavailability of grid power. A bidirectional bridgeless Cuk converter with a switched inductor is designed and analysed for this EV charger. The main advantages of this bidirectional EV charger are regulated battery current and enhanced grid side performance with reduced component count during the bidirectional operation. The steady-state and dynamic performances of the designed battery charger are investigated under distinct operating conditions during EV charging and vehicle-to-home operation. At last, the efficacy of the battery EV charger is tested to comply with IEC 61000-3-2 standard for power quality and bidirectional operation with NEMA PE-5 standard towards battery current.

Keywords: Electric Vehicle, Battery Charger, AC/DC Conversion, Power Quality.

INTRODUCTION

A wide range output voltage charger for electrical vehicles represents a critical component in the rapidly evolving landscape of electric transportation. As the global demand for electric vehicles (EVs) continues to surge, driven by concerns over environmental sustainability and energy efficiency, there is a pressing need for charging infrastructure that can accommodate the diverse range of EV battery voltages and technologies. Traditional charging solutions often face limitations in terms of compatibility and flexibility, as they are designed to operate within specific voltage ranges, requiring separate chargers for different EV models or battery types. In contrast, a wide range output voltage charger offers a versatile and adaptive solution capable of delivering optimal charging performance across a broad spectrum of battery voltages, from low-voltage plug-in hybrids to high-voltage long-range EVs. This introduction sets the stage for understanding the significance and potential impact of a wide range output voltage charger in the context of electric vehicle charging infrastructure. It highlights the increasing demand for electric vehicles worldwide and the need for versatile charging solutions to support the widespread adoption of EVs. Additionally, it hints at the limitations of existing charging technologies and the advantages of a wide range output voltage charger in addressing these challenges. Overall, this introduction provides a comprehensive overview of the topic, laying the foundation for further exploration of the technical specifications, benefits, and implications of wide range output voltage chargers for electrical vehicles.

The advancement in battery technology is a boost to the development of electric vehicles (EV). Moreover, the expedited expansion of charging infrastructure de-limits the range anxiety, which favours the adoption of EVs. Notably, the EV charger topologies are broadly categorized as single and two-stage topologies[1]. The state-of-the-art single-stage EV chargers are considered in [2]-[7]. A single-stage EV charger with high efficiency is presented in[2]. However, the effectiveness of the proposed charger is tested for charging of high voltage batteries. Further, the presented charger uses more components than the available two-stage charger in [1]. An attempt to reduce the number of components in an EV charger is carried out in [3]. In this, the authors have presented the current source converter-based EV charger. The major advantage of this topology is that it does not require a grid side filter. However, the utilization of back-to-back bidirectional switches, increases the design complexity. Moreover, this topology is derived from a full-bridge converter, therefore, it suffers from high circulating current when used with low voltage batteries. Noting this, a soft-switching technique is devised in [4]. The authors have proposed an EV charger with zero voltage switching capability. In this way, this topology has the advantage of low switching losses. However, this topology is experimentally verified for high voltage batteries only. Apart from this, to reduce the size of an EV charger, a differential interleaved boost converter-derived EV charger is presented in [5]. In this, the authors have presented an electrolytic capacitor-less EV charger. However, a step-down converter is required to make it feasible for low voltage batteries. Keeping a buck-boost converter-based battery charger in context to charge the low voltage batteries, a topology has been studied in [6]. In this topology, a Cuk converter-based topology is proposed. In this, the authors have presented a single-stage EV charger that significantly reduces the battery current ripples. However, the performance of the charger is verified for high voltage batteries only. For low voltage batteries, a Cuk-SEPIC-based topology is proposed in [7]. In this, the authors have presented an EV charger that satisfies the applicable standard for the grid current [7] and the battery current [8]. However, the presented EV charger is unidirectional. Noting the increased utilization through bidirectional operation, a comprehensive study is carried out on single-stage bidirectional EV chargers [9]-[10]. Notably, the authors in [9] have presented an interleaved single stage bidirectional EV charger. Since the presented EV charger is derived from a dual active bridge converter, it has the advantage of inherent zero voltage switching, i.e. low switching losses. However, the voltage mismatch between battery voltage and the voltage across the secondary winding of the high frequency transformer creates the circulating current in the secondary side of the converter. Therefore, this EV charger is less suitable for low voltage battery charging. In this context, a single-stage bidirectional EV charger for low voltage battery charging is presented in [10]. Here a current fed topology is given. It is notable, that the back-back to bidirectional switch increases the design complexity of this current fed converter based EV charger. Further, this topology is less suitable for high voltage application, i.e., less suitable for wide voltage range operation. Summarizing above mentioned literature, it is evident that the single-stage bidirectional EV charger with a wide voltage range capability to charge low voltage powered EVs and high voltage powered EVs both, is to be developed. Keeping this necessity in view, a single-stage bidirectional battery charger is realized in this work. The battery current in the developed EV charger remains within the applicable standard. Moreover, it maintains the grid current quality within the IEC 61000-3-2 standard. The key highlights of this work are as follows. The operating principle and design of the presented battery charger are discussed. In this context, the operational principle of the switched inductor-based Cuk converter derived battery charger during the charging operation as well as during the vehicle- to-home (V2H) operation is discussed. The constant-current (CC) charging operation of the battery charger is discussed to verify the operation and behavior of the battery charger with a wide voltage range. This operation is verified through a 72 V battery charging operation, and a 240 V battery charging operation. A 1.5 kW system is designed to analyze the steady-state and dynamic performances of the EV charger under diverse conditions such as distorted and varying grid voltage conditions. The bidirectional operation is verified through the vehicle-to-home operation with a 240V battery.

LITERATURE SURVEY

With the increasing adoption of electric vehicles (EVs) worldwide, there is a growing demand for efficient and versatile charging solutions to support the charging infrastructure. A critical component of this infrastructure is the EV charger, which must be capable of delivering a wide range of output voltages to accommodate different EV models and charging requirements. This literature survey aims to explore existing research and developments in the field of wide-range output voltage chargers for EVs, focusing on various charger topologies, control strategies, and performance evaluations. Several charger topologies have been proposed to achieve a wide range of output voltages for EV charging applications. One commonly used topology is the AC-DC converter, which converts AC grid voltage to DC voltage suitable for charging EV batteries. Within this category, various configurations such as single-phase and three-phase rectifiers, boost converters, and buck-boost converters have been investigated for their suitability in EV charging systems.

Another popular topology is the DC-DC converter, which allows for voltage conversion within the EV charging system. Buck, boost, buck-boost, and bidirectional converters are commonly employed to regulate the output voltage of the charger according to the EV battery's requirements. Additionally, multi-level converter topologies, such as the flying capacitor and cascaded H-bridge configurations, offer enhanced voltage regulation capabilities and improved efficiency for high-power EV charging applications. Effective control strategies are essential for achieving accurate voltage regulation and efficient operation of wide-range output voltage chargers for EVs. Proportional-integral-derivative (PID) control, pulse-width modulation (PWM) control, and predictive control techniques are commonly used to regulate the output voltage of AC-DC and DC-DC converters in EV chargers.

Furthermore, advanced control algorithms, such as model predictive control (MPC), sliding mode control (SMC), and adaptive control, have been proposed to improve the dynamic response, transient performance, and overall efficiency of wide-range output voltage chargers. These control strategies aim to optimize charging efficiency, minimize losses, and ensure stable operation under varying load and grid conditions. The performance of wide-range output voltage chargers for EVs is evaluated based on various criteria, including efficiency, power factor, voltage regulation, harmonic distortion, and reliability. Simulation-based studies using software tools such as MATLAB/Simulink, PLECS, and PSIM enable researchers to assess the charger's performance under different operating conditions and load profiles.

Experimental validation of charger prototypes is also conducted to verify the performance of the proposed topologies and control strategies in real-world EV charging scenarios. Key performance metrics such as charging time, energy efficiency, and thermal management are evaluated to ensure the charger's suitability for commercial deployment and mass adoption. Despite significant advancements in wide-range output voltage chargers for EVs, several challenges and opportunities for future research exist. One area of focus is the development of compact, lightweight charger designs with high power density and energy efficiency. Integration of advanced semiconductor devices, such as silicon carbide (SiC) and gallium nitride (GaN) transistors, can enhance the performance and reliability of EV chargers while reducing their size and weight.

Furthermore, the integration of bidirectional power flow capabilities in EV chargers enables vehicle-to-grid (V2G) and vehicle-to-home (V2H) applications, allowing EVs to serve as distributed energy resources and contribute to grid stability and resilience. Research efforts are needed to develop advanced control strategies and communication protocols to facilitate seamless integration of EVs into the smart grid ecosystem. development of wide-range output voltage chargers for EVs is essential for supporting the widespread adoption of electric transportation and reducing reliance on fossil fuels. Through the exploration of various charger topologies, control strategies, and performance evaluations, this literature survey provides insights into the state-of-the-art developments and future directions in EV charger technology. Continued research and innovation in this field are crucial for advancing EV charging infrastructure and accelerating the transition towards a sustainable energy future.

PROPOSED SYSTEM

To reduce the sensitivity of the thresholds to the driving cycles, the fuzzy logic controller [7,8] was put forward to provide a broader rule for the operating of energy sources. However the deterministic and fuzzy rules are essentially the predetermined rules, which greatly rely on the expert experiences. In addition, the filtration based controller was developed in the literature [9,10], according to the filtration principle, which allocates the high frequency of the demand power to the ultra-capacitor and the low frequency to the battery. As all of the controllers above achieve limited economic performance enhancement, numerous optimal algorithms were applied to set up the controllers for HESS. For instance, dynamic programming (DP) [11,12], particle swarm optimization (PSO) [13,14], and convex optimization [15,16] were employed to explore the potential economic performance of HESS. However, these optimal algorithm-based controllers require the information of the driving cycles in advance, which leads to their poor real-time performance. Therefore, to enhance the real-time application of the controllers, the controllers for speed prediction and driving cycle recognition were invented. The model predictive control (MPC) was introduced to predict the future vehicle speed [17–19]. By predicting a period of the future vehicle speed, a mini-global optimal controller is constructed for the period of the driving cycle. Furthermore, some scholars summed up the characteristics of the existing driving cycles and proposed driving cycle recognition-based controllers to improve the adaptability of the controllers to the driving cycles [20,21]. However, the future speed prediction and the driving cycle recognition are completed on the basis of the existing driving cycles, which means that it is difficult to guarantee an accurate prediction and recognition in the real road all of the time. What is more, the high computing load of the MPC and the driving cycle recognition-based controller limits their further application. In all of controllers above, the traffic condition and the road grade were ignored. It can be observed in the literature [22,23] that the road grade plays a critical role in influencing the power allocation of the controllers. Through establishing the controller considering the road grade, the situation that the controllers deal with is much closer to the real road, so the real-time performance of controllers is further enhanced. Also, the traffic condition is not negligible in the real driving. In the literature [24], a predictive controller adopting the Monte Carlo approach is proposed, so as to handle the information of the traffic condition. In general, most of the research for the control of HESS does not consider the impact of the traffic information on the power allocation. Moreover, in these controllers ignoring the traffic information, some problems, such as the adaptability to driving cycles or computing load, restrict their application to the real road, and in those controllers considering traffic information, the road grade, the traffic condition and the vehicle speed are not taken into account at the same time in a controller. Furthermore, the power allocations of these controllers are mainly determined by the principle of the traditional controllers, which contributes to their poor adaptability to the driving cycles.

SIMULATION RESULT

An analysis of the presented bidirectional single-stage battery charger is carried out at the ideal grid voltage. Moreover, behavior of the battery charger amid the variations in grid voltage is analyzed. Moreover, the efficacy of the presented EV charger with low voltage powered EVs (LEVs) as well as high voltage powered EVs (HEVs) is tested. The results under distinct operating conditions, depicted in Figs. 6- 8, are discussed in detail, as follows.

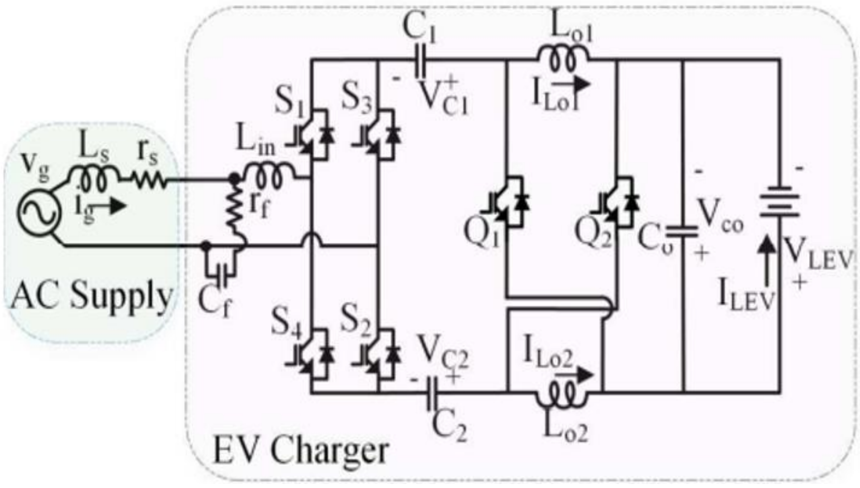

Fig 1. Proposed circuit configuration

The topology of the presented wide voltage range EV charger is shown in Fig.1. Notably, the presented single-stage bidirectional EV charger is derived from the Cuk converter. In this, the input inductor, Lin, is responsible to filter out the high frequency switching harmonics from the grid current. In addition to this, the inductor Lin operates as the input inductor of the Cuk converter. Moreover, switches S1 and S3 collectively behave as the input side switch during the positive half cycle, and switches S2 and S4 collectively behave as the input side switch during the negative half cycle. Furthermore, a switched inductor cell with switches Q1 and Q2 is utilized at the output of this converter to obtain the high voltage conversion ratio. Notably, the output inductors are designed to operate under discontinuous conduction mode (DCM). In this way, the grid's current quality is regulated within the IEC standard. Moreover, a current sensor to measure grid current is not required, since, grid current follows the shape of the output current.

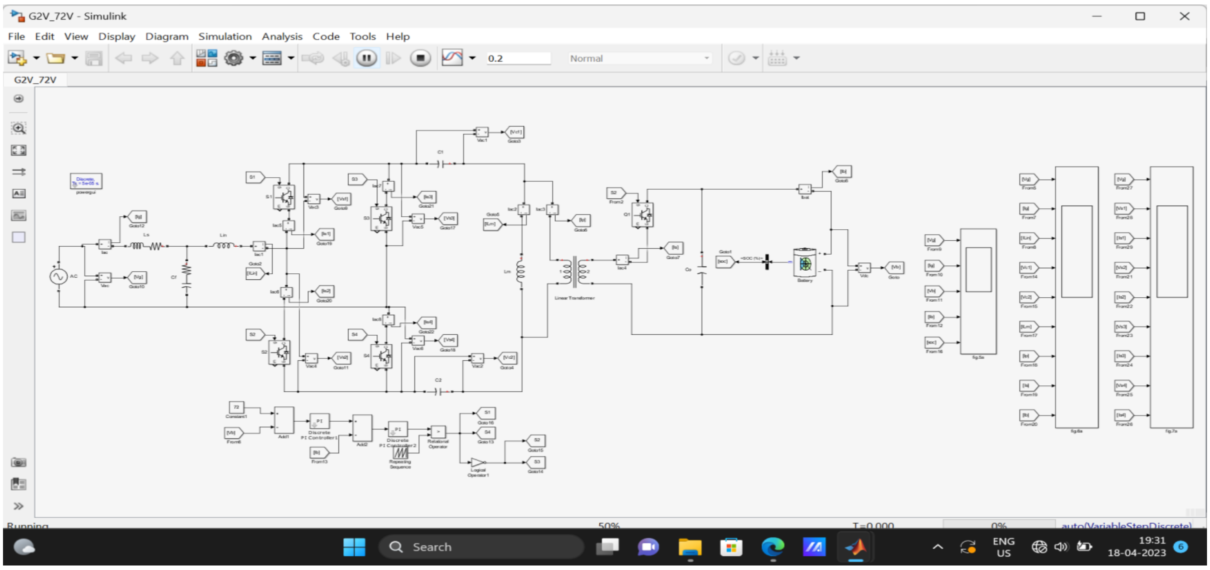

Fig 2.Performance Analysis of LEV Charger with 72V Battery

A wide range output voltage charger for electrical vehicles offers a multitude of features and applications that contribute to its versatility and effectiveness in the rapidly expanding EV market. One prominent feature is its ability to support a broad range of battery voltages, accommodating various EV models and battery technologies. This adaptability eliminates the need for multiple chargers and simplifies the charging process for EV owners and operators. Additionally, wide range output voltage chargers often incorporate intelligent charging algorithms and communication protocols, enabling efficient and reliable charging while ensuring compatibility with different vehicle types and charging infrastructure. Moreover, these chargers are equipped with advanced safety features such as overvoltage protection, overcurrent protection, and temperature monitoring to safeguard both the EV battery and the charging equipment. This ensures safe and reliable operation, minimizing the risk of damage or malfunction during the charging process. Furthermore, wide range output voltage chargers may offer fast charging capabilities, reducing charging times and enhancing the convenience and usability of EVs for drivers.

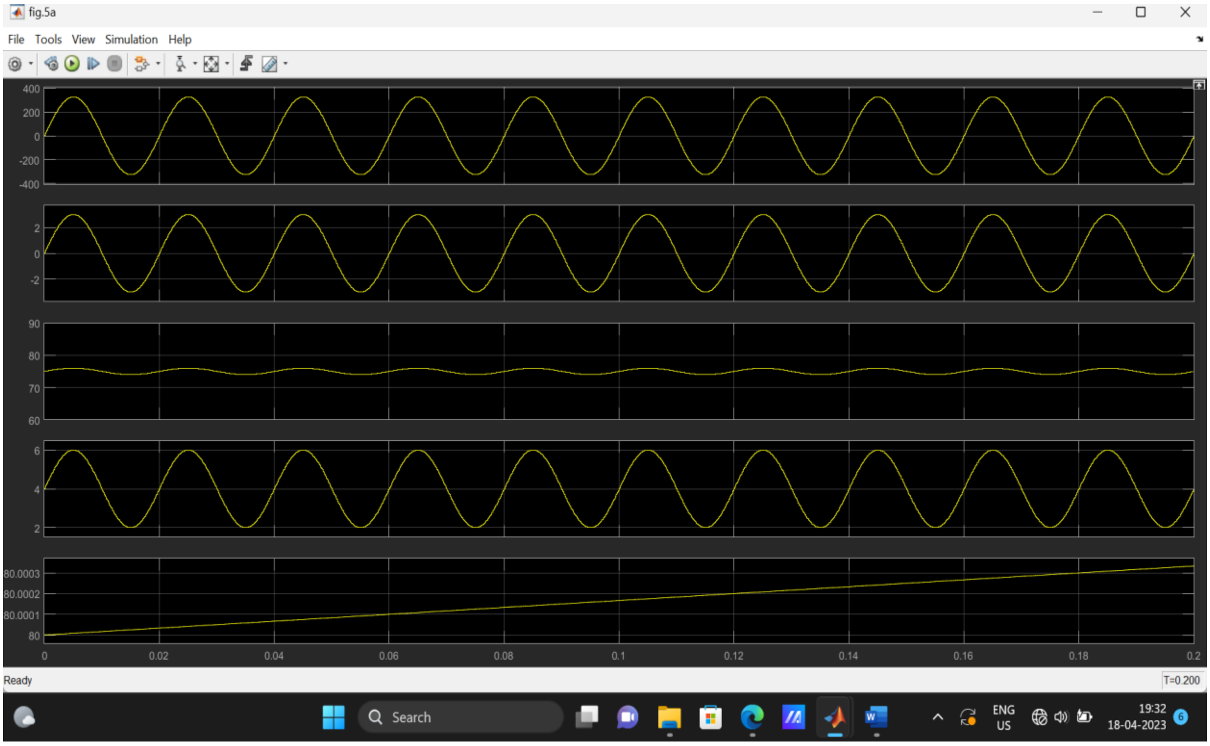

Fig.3 AC side simulation waveforms

In terms of applications, wide range output voltage chargers find widespread use in public charging stations, residential charging installations, fleet charging facilities, and commercial EV charging networks. Public charging stations equipped with these chargers can cater to a diverse range of EVs, attracting more users and promoting the adoption of electric vehicles. Residential charging installations benefit from the flexibility and compatibility of wide range output voltage chargers, allowing homeowners to charge multiple EVs with varying voltage requirements using a single charging unit. Fleet operators can also leverage these chargers to streamline their charging infrastructure and support different types of electric vehicles within their fleets. Additionally, wide range output voltage chargers play a crucial role in the development of smart grid technologies and vehicle-to-grid (V2G) integration initiatives. By enabling bidirectional power flow and communication capabilities, these chargers empower EVs to serve as grid-connected energy resources, contributing to grid stability, renewable energy integration, and demand response programs. Overall, the features and applications of wide range output voltage chargers for electrical vehicles underscore their significance in advancing the adoption and sustainability of electric transportation while driving innovation in the EV charging ecosystem.

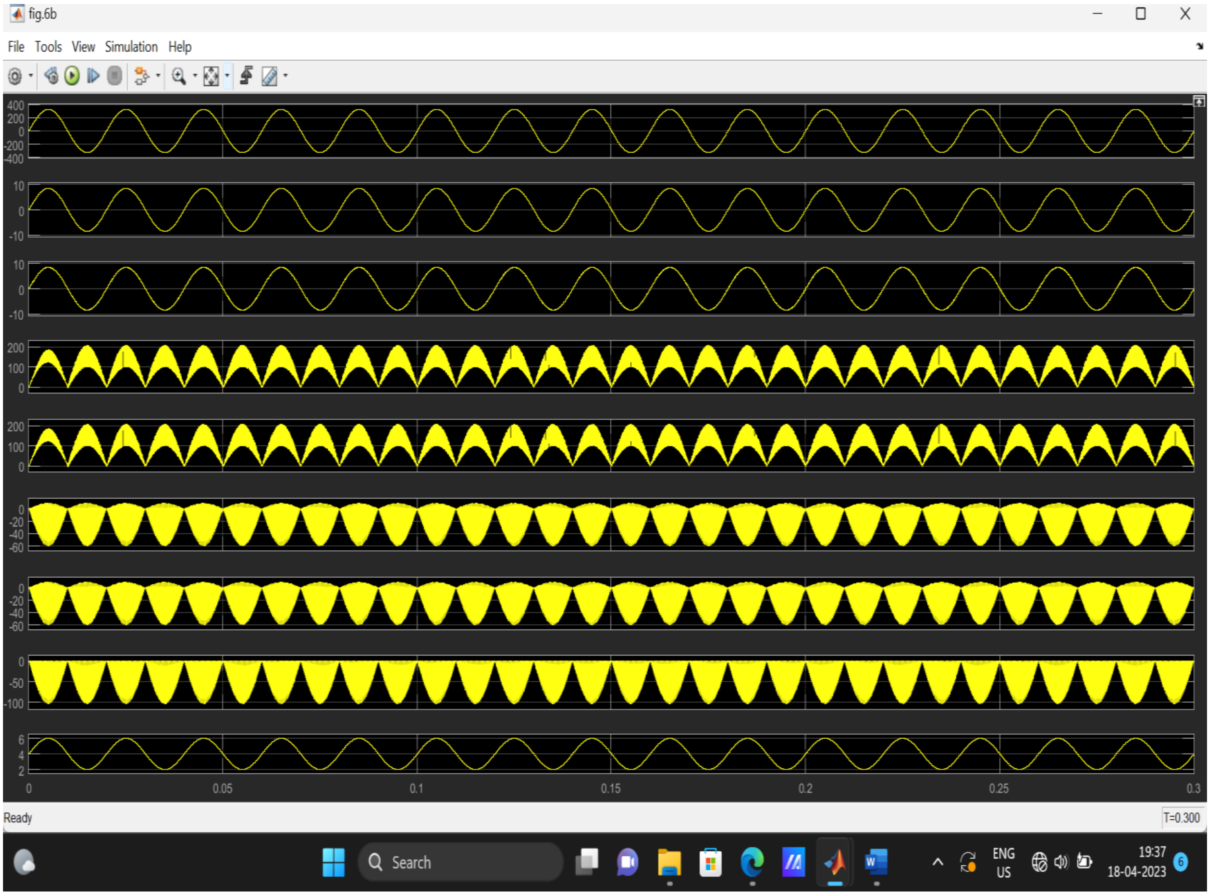

Fig 4. Performance Analysis of LEV Charger with 240V Battery

depict performance of the single-stage bidirectional EV charger during the charging operation of a 240V battery of an EV. The AC side performance of the battery charger. Moreover, the UPF operation is depicted from Fig. 7(a). Moreover, the regulated battery current follows the applicable standard. Furthermore, the harmonic spectra of grid current in Fig. 7(a) show the compliance of operation with applicable standard, as the grid current THD is 2.63%. The voltage and current stresses of the passive components of the EV charger are given. Therefore, the DCM operation of the output inductor is verified in this operation. depicts the voltage and current stresses of the EV charger switches, which are regulated. Therefore, the analysis of charging operation with a 240V battery verifies the suitability of this charger to charge the high voltage powered vehicles.

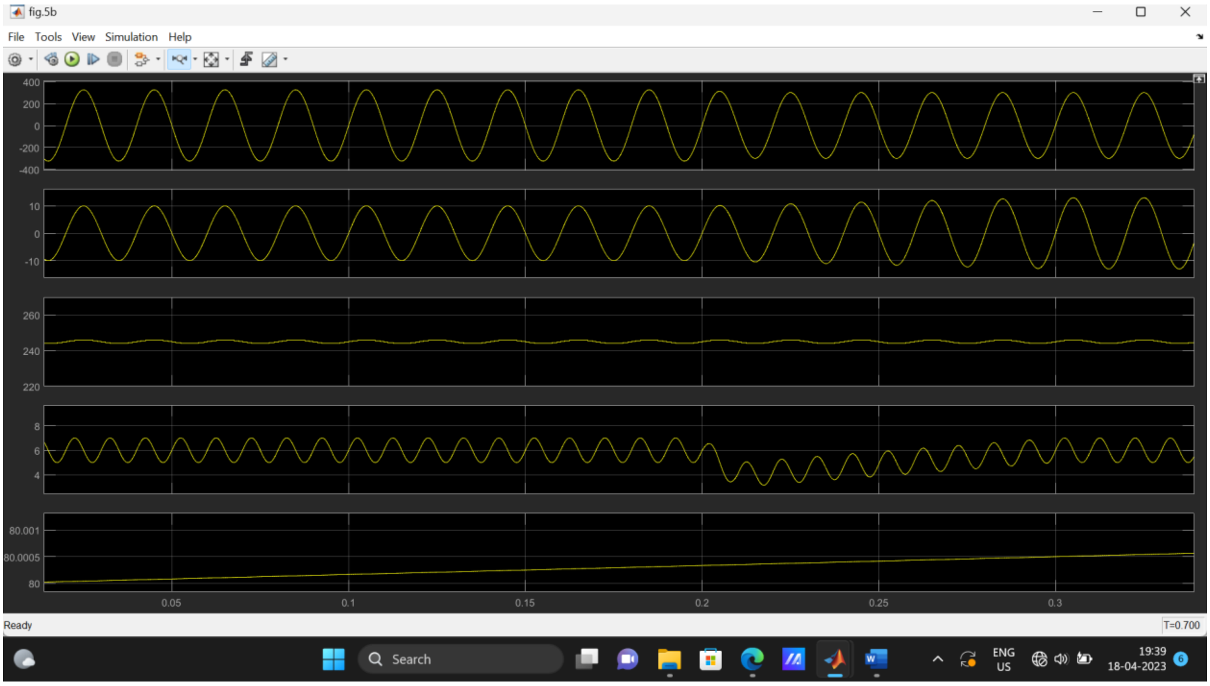

Fig. 5 sag condition waveforms

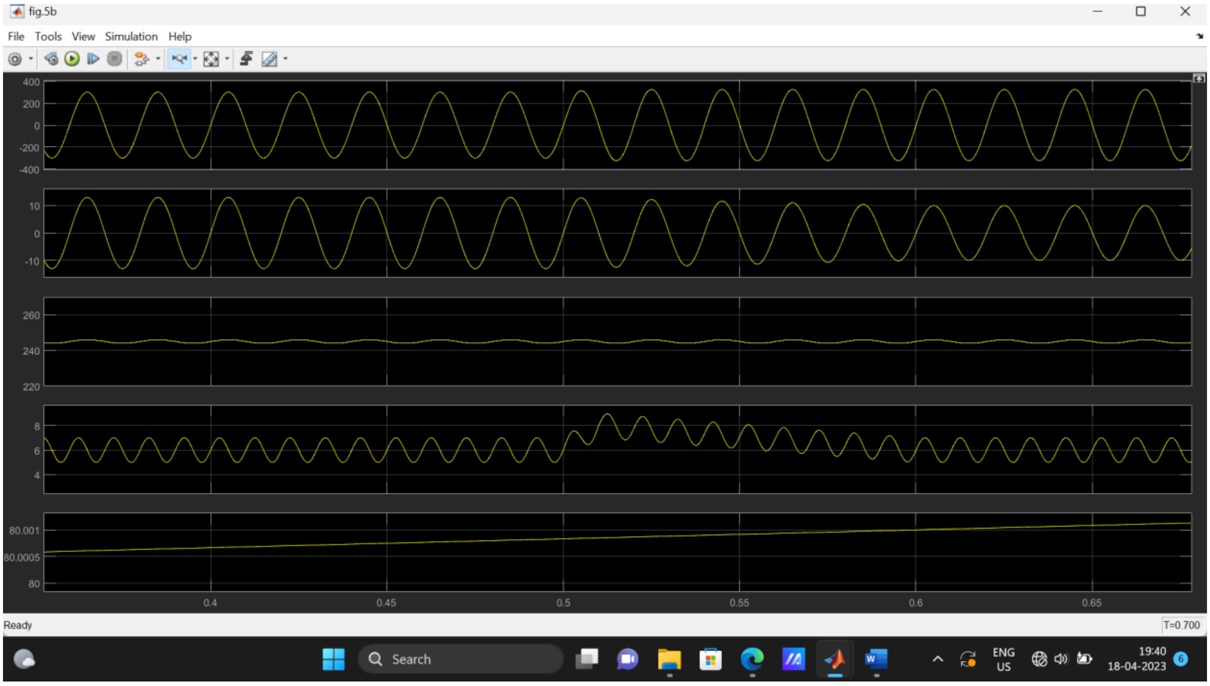

Fig. 6 swell condition waveforms

The bidirectional operation of the EV charger increases its utilization. In this context, the vehicle-to-home operation prevails as the backup home supply. Therefore, in this work, the bidirectional operation of the battery charger is verified through V2H operation.

CONCLUSION

A switched inductor-based Cuk converter-derived single stage bidirectional EV charger is realized in this work. The main advantage of this EV charger is its wide output voltage range. Therefore, it is capable to charge low voltage powered EVs (LEVs) as well as high voltage powered EVs (HEVs). Therefore, the performance of the presented charger is analyzed during the charging operation of batteries with a nominal voltage rating of 72 V and 240 V. Moreover, the efficacy of EV charger is tested to comply with bidirectional operation with NEMA PE-5 standard towards battery current and IEC 61000- 3-2 standard for power quality. Furthermore, the steady-state performance and dynamic performance of the presented EV charger are verified under distinct operating conditions, i.e. during ideal as well as varying grid voltage conditions.

REFERENCES:

[1] A. Khaligh and S. Dusmez, "Comprehensive Topological Analysis of Conductive and Inductive Charging Solutions for Plug-In Electric Vehicles," IEEE Trans. Veh. Tech., vol. 61, no. 8, pp. 3475-3489, Oct. 2012.

[2] M. Abbasi, K. Kanathipan and J. Lam, "An Interleaved Bridgeless Single Stage AC/DC Converter with Stacked Switches Configurations and Soft Switching Operation for High Voltage EV Battery Systems," IEEE Trans. Ind App., Early Access, Mar. 2022.

[3] D. Zinchenko, A. Blinov, A. Chub, D. Vinnikov, I. Verbytskyi and S. Bayhan, "High-Efficiency Single-Stage On-Board Charger for Electrical Vehicles," IEEE Trans. Veh. Tech., vol. 70, no. 12, pp. 12581-12592, Dec. 2021.

[4] P. Amiri, W. Eberle, D. Gautam and C. Botting, "A CCM Bridgeless Single-Stage Soft-Switching AC-DC Converter for EV Charging Application," IEEE Energy Conv. Cong. and Expo. (ECCE), pp. 1846-1852, October,2021.

[5] A. Tausif, H. Jung and S. Choi, "Single-stage isolated electrolytic capacitor-less ev onboard charger with power decoupling," CPSS Trans. Power Elect. and App., vol. 4, no. 1, pp. 30-39, Mar. 2019.

[6] D. Patil and V. Agarwal, "Compact Onboard Single-Phase EV Battery Charger With Novel Low-Frequency Ripple Compensator and Optimum Filter Design," IEEE Trans. Veh. Tech., vol. 65, no. 4, pp. 1948-1956, Apr. 2016.

[7] R. Kushwaha, B. Singh and V. Khadkikar, "An Isolated Bridgeless Cuk– SEPIC Converter-Fed Electric Vehicle Charger," IEEE Trans. Ind. App., vol. 58, no. 2, pp. 2512-2526, Apr. 2022.

[8] Atseries, Appl. Note JD5013-00, Nov. 2006.

[9] H. Kim, J. Park, J. Lee and S. Choi, "A Simple Modulation Strategy for Full ZVS of Single-Stage Electrolytic Capacitor-less EV Charger with Universal Input," in IEEE Trans. Power Elect., Early Access, Apr. 2022.

[10] A. K. Singh, R. Prasanna and K. Rajashekara, "Modelling and Control of Novel Bidirectional Single-Phase Single-Stage Isolated AC/DC Converter with PFC for Charging of EVs," IEEE Intern. Conf. on Electro/Info. Tech. (EIT), pp. 0661-0666, May 2018.