A Bidirectional ANN-Based On-Board LEV Charging System

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Abstract. This paper introduces a Bidirectional Artificial Neural Network-Based On-Board Charging System for light electric vehicles (LEVs), addressing limitations of unidirectional systems in smart grid environments. The proposed solution aims to solve present challenges, such as low efficiency and high volume, by providing improved performance for supply and battery- side operations. To accomplish ripple-free loading and unloading, it uses a two- stage construction with two stages, AC-DC and DC- DC are employed along with a non-isolated bidirectional switched inductor buck-boost (BSIBB) converter. The high gain capability of the BSIBB converter eliminates the need for transformers, reducing total harmonic distortion (THD) and ensuring effective grid charging. Design and performance analyses validate the system's suitability for LEV charging applications. ANN is artificial intelligence-based algorithm which gives better performance than state of art controllers.
Keywords- Artificial Neural Network(ANN), light electric vehicles LEV, bidirectional switched inductor buck-boost (BSIBB), bidirectional inductor-based buck-boost converter (IBBBC).

I. INTRODUCTION

The primary aim is to address the limitations of existing unidirectional charging systems, allowing for efficient charging from the grid as well as discharging energy back to the grid when required. This bidirectional capability aims to enhance the integration of LEVs into smart grid scenarios, improving overall grid flexibility and energy management. The main objectives of the thesis concentrate on developing following:

Developing a simulation model for fast DC charging stations for electric vehicles (EVs).Creating a simulation model for implementing a constant current control strategy in battery chargers. Designing control systems to enhance the power quality of inverter control systems. Using a simulation, demonstrating ways to set up a DC fast charging station for the purpose of implementing Grid-to-Car (G2C) and Car-to-Grid (C2G) infrastructure in a microgrid. In this configuration, off-board chargers are used to connect EV batteries to the DC bus. A grid-connected inverter connects the DC bus to the utility grid by means of a step- up transformer and an LCL filter.

The current unidirectional charging systems for light electric vehicles (LEVs) pose limitations in smart grid integration due to their one-way power flow. To address this, a bidirectional on board charger topology is proposed, addressing supply and battery side performance issues while ensuring grid compatibility. This topology employs a two-stage structure DC-DC and AC-DC stages, utilizing a non- galvanic bidirectional inductor-based buck- boost converter for efficient charging. Unlike conventional methods, it eliminates the need for transformers, enhancing efficiency. Additionally, EV batteries are explored as potential energy storage in micro-grids, enabling vehicle-to-Grid (V2G) and grid-to-Vehicle (G2V) power transfers. A micro-grid test system with a fast charging station demonstrates active power regulation and minimal harmonic distortion, showcasing the feasibility of V2G-G2V integration for grid management.

To promote eco-friendly transportation, e- mobility has gained prominence, with various types of electric vehicles (EVs)available, including battery EVs(BEVs), Plugin HEVs (PHEVs), and Hybrid EVs (HEVs). Notably, Small EVs (SEVs) such as electric motorcycles (EMs) and electric tricycles (ETs) are experiencing rapid adoption globally. [1] However, existing LEV charging systems suffer from performance issues such as low efficiency, high volume, and stress on semiconductor devices, posing obstacles to their sustainable growth in the current energy-efficient market. [2]

Existing LEV chargers typically only support unidirectional power flow, limiting their usefulness in grid support and hindering their integration into smart grid environments. Onboard chargers, compared to off board chargers, offer greater convenience and time utilization for vehicle owners due to their installation directly on the vehicle.[3-4] Bidirectional power flow capability, available in both onboard and offboard chargers, is particularly promising as it enables smart operation during normal and abnormal grid conditions, mitigating negative impacts on the electrical network.

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Thus, bidirectional onboard charging systems are considered ideal for LEVs, with various topologies proposed in previous studies for EV/LEV applications. [5-9]

Bulky filters are required at both the supply and load ends of single-stage charger topologies because they frequently cause slow- varying charging current ripples and significant voltage and current stress on active devices. For medium- to high-power applications, two-stage charger topologies are recommended. In these setups, the two-way AC-DC front-end stage guarantees optimal performance attributes at the power source, in the meantime the DC-DC back- end stage regulates battery current and achieves desired voltage enhancement between the DC link and battery packs dis examined throughout both scenarios Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) operational states. [10-12] Although high-frequency transformer (HFT)-based converters are commonly used in the back-end of on board chargers, they require Refined design and precise management for attaining targeted efficiency, with leakage inductance sometimes limiting switching frequency due to increased voltage stress across active switches.

Additionally, concerns regarding expenses and dimensions linked with it high-frequency transformers(HFTs) pose challenges for affordable and space-efficient solutions for charging light electric vehicle (LEVs)[13-16] While transformer less onboard charging solutions have been demonstrated for EVs, transformer less solutions with bidirectional power capability for LEVs have been overlooked. Hence, this paper introduces a bidirectional on board charger topology with a transformer less, two-stage structure for LEVs. In both grid-to-car (G2C) and Car- to-grid (C2G) modes, energy transfer between the grid and battery is managed by a complete full- bridge AC- DC converter positioned at the input stage. The presented topology achieves the desired voltage gain without a transformer, employing a switched inductor configuration for the DC-DC phase. The simplicity and effectiveness of the control architecture enable satisfactory achievement of control objectives. The operational principles analyzed are the functionalities of the charger in V2G and G2V and its operation, design, and control are verified using MATLAB Simulink, with corresponding results provided for verification purposes.

II. LITERATURE SURVEY

The authors provide a comprehensive overview ofthe technical aspects related to vehicle- to-grid (V2G) technologies, focusing on their impact on distribution systems and utility interfaces. The review encompasses various technical materials published in this periodical throughout the year, including papers, correspondence, and reviews, along with any relevant items from previous years that we recommented upon or corrected.

The author index facilitates easy access to each item, listing the primary entry under the first author's name, along with co-authors' names, publication details, and pagination. Similarly, the Subject Index provide sentries categorized under appropriate subject headings along side publication details, aiding in efficient retrieval of relevant information." [1]

This article offers a minimized sensor-based bridgeless boost (BLB) power factor correction (PFC) converter combined with a full-bridge inductor-inductor capacitor (FBLLC) rectifier for the purpose of loading electric vehicles (EVs). The converter functions in two stages: an FBLLC converter changes the output voltage for steady current/steady voltage (CC/CV) loading of the EV battery, while the PFC-BLB converter, the first stage, operates in continuous conduction mode to ensure efficient power transmission. While the FBLLC converter uses pulse frequency modulation for CC/CV charging, the BLB converter functions as operated at a adjust frequency using pulse width modulation. [2]

This study addresses the challenges posed to electrical grids by the increasing presence of electric vehicles (EVs), driven by global warming concerns and environmental issues. The growing number of EVs capable of G2C and C2G interactions raises energy quality issues in electrical grids. The research investigates current and future EV conditions and recent studies on EV integration, high lighting challenges and proposing solutions to mitigate their impact on electrical grids. [3]

This paper introduces a novel approach for controlling a bi-directional electric vehicle (EV) charger using a dual integral sliding mode control (DSMC) anda flexible phase-shift algorithm. The charger utilizes a front-end bridge-less converter, with an interleaved phase- shifted configuration preferred for its reduced switching loss and fewer passive filter components. The paper presents a flexible grid-frequency detection method to address this issue and improve zero-crossing detection (ZCD) accuracy. Additionally, the DSMC offers flexibility in dealing with parametric variations, while modifications to the phase-shift algorithm consider battery charging dynamics. The proposed control strategies are validated through simulation and laboratory prototype experiments, demonstrating improved charging performance under severe grid conditions for a 3.3 Kilowatt EV charger. [4]

A two-way on-board charger (BODC)for electric vehicles (EVs) integrates an entire-bridge two-way DC-AC inverter with a two-way CLLLC DC-DC converter, offering flexibility in charging and discharging. The DC-AC inverter supports AC-DC operation including power factor correction (PFC), while the modified CLLC DC-DC converter enhances efficiency with dual resonant capacitors. . A 3.3 kW BODC prototype demonstrates various modes, including battery charging show casing its versatility, car-to- grid (C2G),car-to-house (C2H), and functionality in EV applications. [5]

The rapid growth of electric vehicles (EVs) presents opportunities to enhance clean energy utilization in automotive sectors. On-board chargers (OBCs) are favored for their ease of Installation and cost-effectiveness in EVs. As space constraints and charging efficiency become critical, there's a rising interest in bidirectional power flow solutions to enable vehicle-to-grid capabilities. This paper offers a comprehensive examination of bidirectional OBCs, available products, industry standards, components, smart operation modes, and covering current architectures. It reviews promising topologies, such as single- stage and two-stage structures explores future trends and challenges, including wireless charging systems system integration,
thermal management, and wide band gap technologies. [6]

III. PROPOSED METHOD

Proposed method has included main objectives as DC fast charging for EV design, controlling constant current, power quality improvement and using ANN advanced architecture based control strategy , bidirectional EV on board fast charging which can be used in both G2V and V2G.

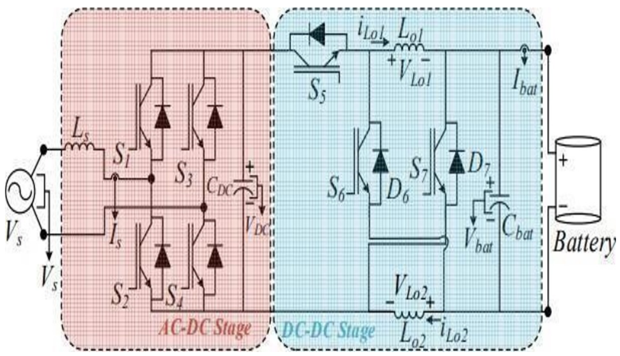

Figure1. For LEV,On board Charging Topology(Bidirectional)

Different modes such as V2G and G2V are analyzed for understanding operation of onboard charging topology. In the charging mode of V2G, S6,S7 and D5 are used to control battery discharging current as well as D7, D6 diodes with switch S5 are turned red (OFF).In thechargingmodeofG2V, battery can be controlled by S5, D7 and D6 while S6, S7 switches, D5 diode is Red (OFF) condition.

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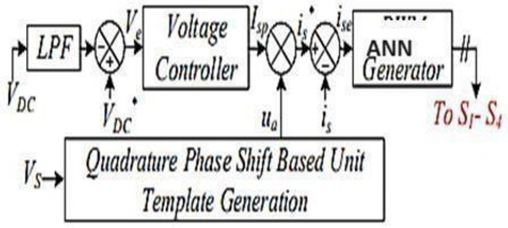

Figure 2.Control architecture for AC-DC stage using ANN

A control architecture for proposed method includes following blocks ,

a) LPF(Low pass filter)
b) Voltage controller
c) ANN generator
d) Template Generation

LPF(Low Pass Filter)

For getting smooth DC supply by passing only desired DC components the LPF is used. Noise of high frequency is removed using this filter in AC voltage rectification. LPF is most important component while converting AC to DC.

Voltage Controller

Desired level of voltage can be ensure using voltage controller in AC to DC conversion. Load will get desired power which is controlled by duty cycle and this duty cycle can be controlled by voltage controller

ANN Generator:

Control architecture uses ANN algorithm for controlling different parameters in the bidirectional onboard LEV charging. In ANN we have to determine initial weights, activation function, single layer with multiple neurons, multiple layers.

Generation of Template:

Neural network creates the pattern or template in template generation. In bidirectional onboard charging using ANN includes different charging conditions such as state of charge of battery, varying input voltage, current. Performance and control strategy is well maintained by ANN generator so that it can be useful in real life scenarios of charging from power source used externally for EV battery charging and grid power supply (Vehicle to grid if needed).
The proposed control architecture provides efficient and adaptive on board charging for EV application.

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IV. RESULT ANALYSIS

Using the Simulink toolbox in MATLAB, the objectives and design targets of the bidirectional onboard charging setup were thoroughly evaluated. Results depicted in Fig. 4 showcase the system's ability to achieve high power factor operation during Grid-to-Vehicle (G2V) mode, maintaining minimal harmonic distortions in the supply current (Is). Additionally, a steady charging current of 40 A (positive polarity) was supplied to the battery, ensuring ripple-free operation. Moreover, the direct current link voltage (VDC) remained consistently regulated at 400 V, highlighting the stability of the system during steady-state conditions.

The operating properties of the BSIBB DC- DC converter's active and passive components are further examined in Section III and shown in figure. During Grid-to-Vehicle (G2V) mode, the conduction of diodes D6 and D7is evident when switch S5isturned OFF, as indicated by the negative current through S6 and S7 (IS6 and IS7). The BSIBB DC- DC converter effectively mitigates the current strain on magnetic elements is regulated while sustaining minimal voltage strain on semiconductor devices. In the same vein, as shown in Fig. 5, the battery maintains similar performance characteristics on both the line and load sides while supplying continuous power to the grid when operating in Vehicle-to-Grid(V2Gmode. Despite the interchange of conduction in semiconductor switches, the voltage pressure across them stays within predetermined boundaries, as illustrated in Fig. 6.

The onboard charger configuration effectively constrains total harmonic distortion below 5% in both Grid-to-Vehicle (G2V)and Vehicle-to- Grid(V2G) modes, meeting various standards. Additionally, the charger demonstrates robust performance against line and load disturbances, ensuring uninterrupted charging of LEVs even with wide variations in supply voltage and loading conditions. The controller maintains smooth adjustment of supply current magnitude without compromising high power factor operation, affirming the efficiency of the two way charging structure for onboard LEVs.

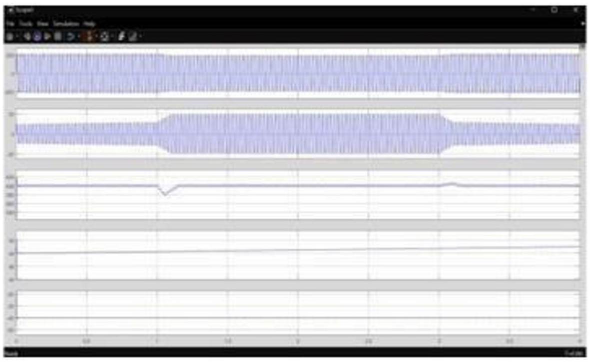

Fig 3 On-board bidirectional charger input vtg vs current

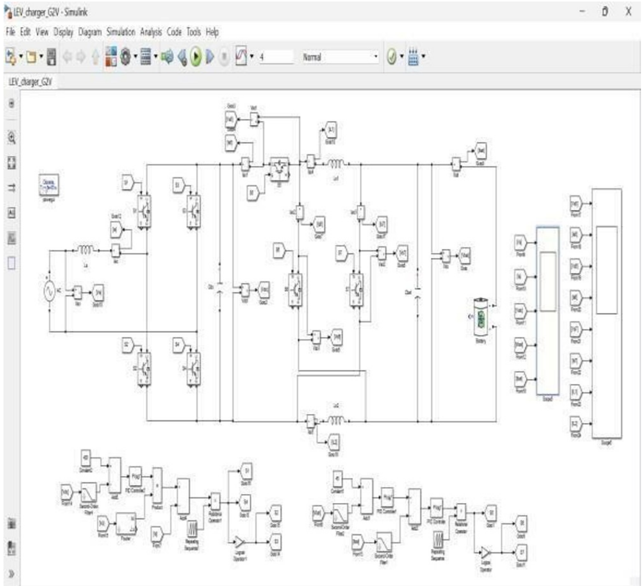

Fig 4. Simlink Model for Proposed Method

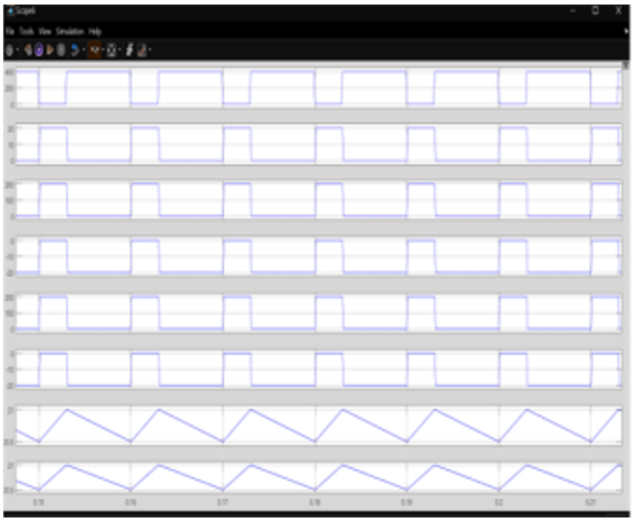

Fig 5. G2V on-board charger current vs time

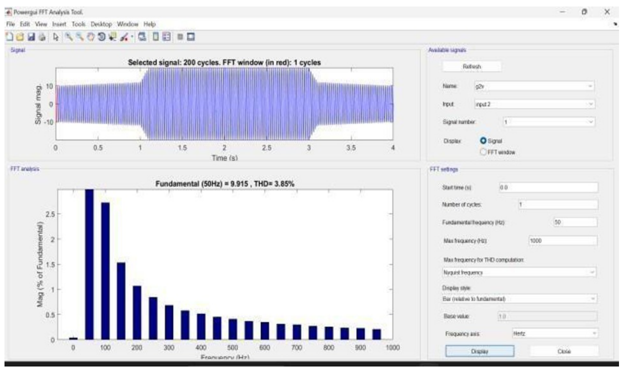

Fig 6. Power Guige available signals of FFT Analysis

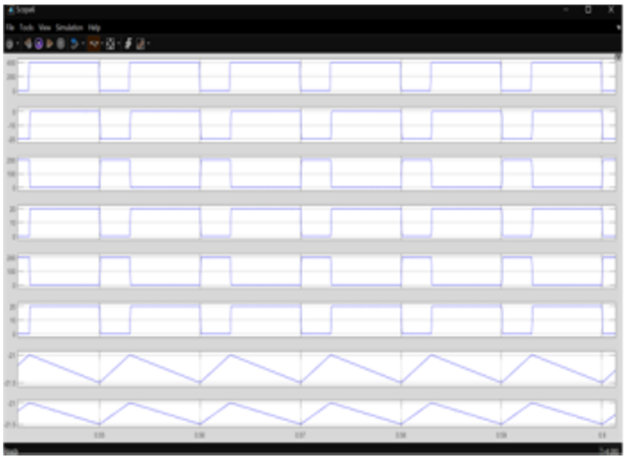

Fig 7. V2G on-board charger current vs time

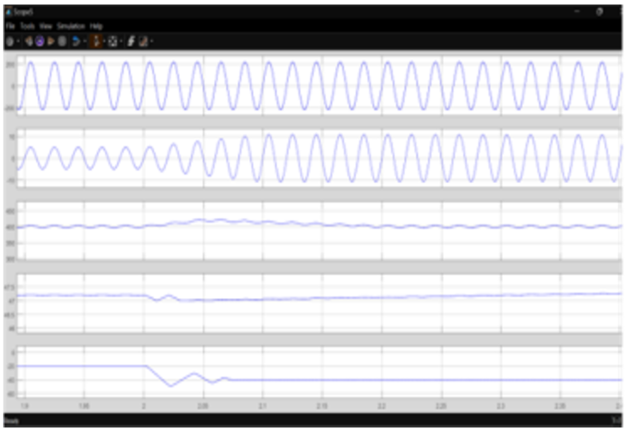

Fig 10.ANN based charging system for voltage and current G/V

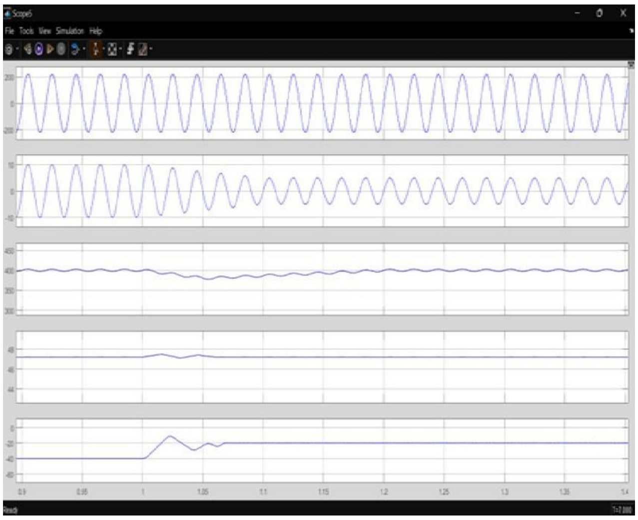

Fig 8. Scope of Waveform

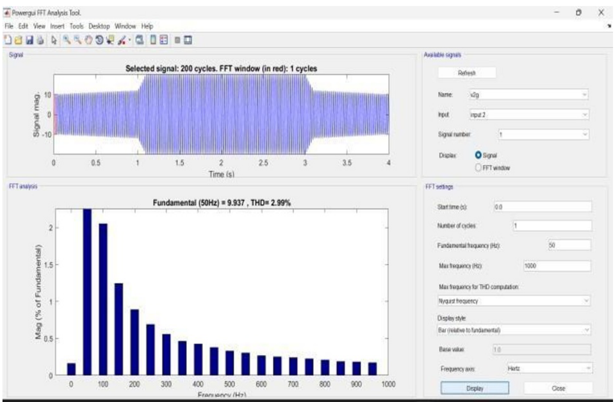

Fig 9. Scope of FFT Analysis

V.CONCLUSION

In this work introduces a Bidirectional ANN- Based On-Board LEV Charging System, offering efficient charging for LEVs along with the capacity for power transfer from vehicles(V2G) to the grid The system provides high power factor and ripple-free charging/discharging by using a two-tiered design featuring a complete bridge active AC-DC stage and bidirectional switched inductor buck-boost (BSIBB) DC- DC stage. Detailed operational principles and control implementation have been provided, supported by relevant results, validating the design and control objectives. Extension ANN model based controller gives better performance than state of art techniques.

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