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Power Factor Correction of SI-SEPIC Converter Cascaded with Flyback Converter for EV Applications

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ABSTRACT: This paper presents the control and modelling of an EV charger. The proposed EV charger consists of two-stage power conversion, the initial stage consists of SI-SEPIC converter, which inherently provides the power factor correction of the EV charger at the source, and the later consists of Fly back converter. Collective combination of these two converters for the EV charger results for the operation of converter at reduced duty ratio resulting which efficiency of the converter is increased. This work mainly focuses on designing the components of the converter and power factor correction using PWM and SPWM controller techniques in MATLAB environment. The environment. To counteract this, one solution is the adoption of electric vehicles (EV) for transportation requirements. In this regard, one category of EVs that requires special attention is light electric vehicle (LEV), mainly because of their wide potential in public transportation—especially in developing countries. To realise widespread adoption of LEVs for this purpose, it is imperative to make their charging systems more robust. Consequently, the subject of LEV charging has gained considerable traction, and numerous research works have been reported on this subject in recent years. Hence, this paper aims to chronicle recent research developments on LEV charging techniques, by placing special attention on DC-DC converter topologies used in both on-board and off-board chargers. This review explores recent LEV charger DC-DC converters in literature by segregating them into isolated and non-isolated topologies. Lastly, this work explores challenges and emerging trends in LEV charging, which can potentially be explored by researchers in the future. This article explains five innovative approaches for adapting boost converters to function as standard DC-DC converters to capture solar energy, consisting of (i) voltage-multiplier cell, (2) coupled inductor, (3) coupled inductor and switch capacitor, (4) cascaded topology and (5) voltage-lift technique. Because of the boost converter's restrictions, it is necessary to deliver high performance.

KEYWORDS: SI-SEPIC converter, PWM and SPWM controller, EV charger, Fly back converter, MATLAB environment.

I. INTRODUCTION

The conventional EV charger consists of Diode Bridge. Rectifier for AC to DC conversion. Due to the presence of DBR, these EV chargers suffer from several PQ issues i.e. It draws non-sinusoidal and peaky current from the mains, resulting in a very large amount of THD which badly affects the life of distributed transformer and many other equipment, that are present in the charger. This makes the requirement to add single-stage or double-stage Unity Power Factor based converter between the DBR and the DC-Link Capacitor. Generally, a two-staged AC-DC converter is chosen for improved Power Quality-based EV chargers as it offers the advantage of less value of DC-Link capacitor, high reliability and voltage stress across PFC device is reduced. Single-stage PFC converter have high value of current and voltage stress across the PFC device this is the reason it is generally not Used. A general configuration of a dual-stage EV charger. In two-staged EV charger, the initial stage comprises of DBR and a DC-DC converter, which is used for AC-DC conversion and PFC respectively. Then, a high-frequency isolation DC-DC stage is used to isolate the battery from AC grid, it is done for various safety issues.

The worldwide concern of reduced energy consumption has seen an outstanding growth due to increased global warming and reduced fossil fuel reserves [1], [2]. The electric mobility presents an incredible alternative to the conventional fuel powered vehicles. However, the integration of these electrified vehicles to the transportation sector, largely depends upon the efficient control strategies to reduce the harmonics injected to the grid [3] and to achieve a unity power factor (UPF) operation, which is recommended as per the IEC61000-3-2 guidelines [4]. This improved power factor (PF) based operation is achieved with PF correction converters at front-end. Therefore, researchers are giving attention to improve these PFC converters to provide better efficiency and reliability under all operating conditions.

The typical architecture of an EV charger consists of an AC–DC converter, a boost, buck or preferably, buck-boost PFC converter at front-end followed by an isolated converter. The charging characteristic of this charger, depends upon performance of the isolated converter as the output voltage and output current are strictly regulated. An LLC resonant converter [5] with the significant advantages such as improved efficiency, reduced EMI noise and increased power density at wide input range is quite popular as an isolated converter. The boost or buck-boost PFC converter, is seen to be highly efficient, still the overall efficiency of the conventional EV charger is observed to be significantly low in two stage EV charger. This happens as the resonant converter, at next stage cannot operate at the exact resonant frequency.

1.1 IMPROVED SEPIC CONVERTER BASED EV CHARGER

The improved SEPIC converter based EV charger . This charger consists of a PFC converter at front-end to provide an improved PQ characteristics and an isolated converter to control the current through the EV battery during charging. The output of this PFC converter with high voltage gain, is maintained at constant 300V. The design of this converter is selected in DCM, which results into reduced number of sensors as compared to continuous conduction mode (CCM) based design in the PFC circuit. Therefore, the cost and control complexity of the converter, are reduced. The proposed converter is the modified version of conventional SEPIC converter with the addition of few auxiliary components to increase the voltage gain higher than the other non-isolated SEPIC converters.

1.2 POWER FACTOR CORRECTION (PFC)

Power factor correction (PFC) is a technology that improves the power factor of an electrical installation by realigning the current and voltage waveforms. Power factor correction (PFC) is the set of mechanisms built into a power supply circuit to raise the power factor (PF). PFC is commonly incorporated into computer power supplies to increase their PF. A circuit's PF is the ratio of real power to apparent power. Power factor is defined as the ratio of energy a device is capable of transmitting to the output versus the total amount of energy it takes from the input power source. It is a key figure of merit for the design of electrical devices, especially due to the regulations put in place by countries and international organizations like the EU, which define the minimum power factor or maximum level of harmonics a device must have in order to be sold in the European market.

II. LITERATURE SERVEY

2.1. Electric Vehicle Battery Charger with Improved Power Quality Cuk-Derived PFC Converter

AUTHOR- B. R. Ananthapadmanabha,¹ Rakesh Maurya,¹ Sabha Raj Arya¹ and B. Chitti Babu²

YEAR-2021

DESCRIPTION- In this paper, an improved power quality converter derived from Cuk converter is proposed for the electric vehicle battery charging under universal-input voltage operation. The proposed converter offers high voltage gain, low voltage stress across the switch, lower conduction losses and reverse recovery losses during low input voltage condition. It yields improvement in efficiency at the low input supply voltage over the single-switch converters such as buck-boost, fly-back, SEPIC, and Cuk topologies and two-switch buck-boost cascaded converters.

2.2. Isolated bidirectional DC-DC Converter: A topological review

Author - Mohammad Aslam Alam , Ahmad Faiz Minai ^a, Farhad Ilahi Bakhsh ^b

Year-2022

DESCRIPTION- Bidirectional DC-DC converters (BDCs) are certainly an important power electronic converter for managing bidirectional power flow in various applications. It offers the ability to flow power in both directions, which is useful in systems with renewable energy sources and energy storage. BDCs are becoming increasingly important in

various applications, including renewable energy systems, electric vehicles, and energy storage. The development of new BDC topologies and control strategies is expected to further improve their efficiency and performance.

2.3. Isolated DC-DC Power Converters for Simultaneous Charging of Electric Vehicle Batteries: Research Review, Design, High-Frequency Transformer Testing, Power Quality Concerns, and Future

AUTHOR - Srinath BelakavadiSudarshan, and Gopal Arunkumar
YEAR-2022

DESCRIPTION- The transportation industry is transitioning from conventional Internal Combustion Engine Vehicles (ICVs) to Electric Vehicles (EVs) due to the depletion of fossil fuels and the rise in non-traditional energy sources. EVs are emerging as the new leaders in the industry. Some essential requirements necessary for the widespread adoption of EVs include sufficient charging stations with numerous chargers, less to no wait time before charging, quick charging, and better range. To enable a quicker transition from ICVs to EVs, commercial organizations and governments would have to put in a mammoth effort, given the low number of installed chargers in developing nations such as India.

III. PROJECT DESCRIPTION

3.1. EXISTING SYSTEM

- In two-staged EV charger, the initial stage comprises of DBR and a DC-DC converter, which is used for AC-DC conversion and PFC respectively. Then, a high-frequency isolation DC-DC stage is used to isolate the battery from AC grid, it is done for various safety issues.
- Various DC-DC converters that can be used for PFC converters includes boost converter, buck converter, buck-boost converter, zeta converter, cuk converter etc and DCDC converters for isolation stage includes flyback converter, forward converter, half bridge and full bridge converter etc. The buck and boost converters have discontinuous input and output current respectively, high input voltage ripple and high electric stress across the device but it requires lesser number of components. Whereas in Buck-Boost configuration, output voltage is negative and input voltage ripple is more.

3.2. PROPOSED SYSTEM

Conventional PFC (Power Factor Correction) circuits in EV (Electric Vehicle) battery chargers have the efficiency limitation due to high conduction loss associated with a diode bridge rectifier (DBR) at the input. To mitigate this issue, a bridgeless (BL) single ended primary inductance converter (SEPIC) with improved power quality, is presented in this paper. The input current shows a unity power factor operation over the entire charging duration. Due to elimination of DBR and the current conduction through relatively fewer number of devices, conduction losses are significantly reduced. This, in turn, improves the charger efficiency as compared to conventional BL SEPIC converter. The overall performance of proposed charger is illustrated with the help of various operating modes, design equations, simulation based performance and experimental validation under steady state as well as over wide fluctuations in AC mains voltage. The EV battery is charged at constant current/ constant voltage control mode, which provides satisfactory results for improved efficiency and inherent PFC, thus, improving overall performance of the charger.

3.3. BLOCK DIAGRAM

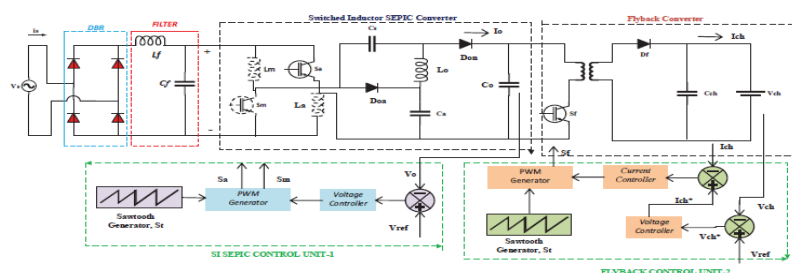


Fig. 2. Proposed SI-SEPIC Converter cascaded with flyback converter for Battery Charging

Modes of Operation of SI-SEPIC converter cascaded with Flyback converter. (a) Mode-1, (b) Mode-2, (c) Mode-3

IV. RESULT AND DISCUSSION

This paper presents a non-isolated switched inductor sepic (SI-SEPIC) converter topologies for photovoltaic boost applications. In this paper three novel switched inductor Sepic (SI-SEPIC) converters topologies are demonstrated which retrieved from conventional sepic converter by replacing inductor by switched inductor. The structure formed with two inductors and three diode in which inductor gets charged in parallel and discharge in series is called as switched inductor. This gives proposed SI-SEPIC topologies to have large voltage gains compared with the conventional sepic converter. The proposed converters are analysed in continuous conduction mode (CCM). Since the proposed converters topologies avoids cascade connections and transformers, simple and inexpensive topologies are obtained for photovoltaic boost applications. The proposed three converters have been designed for 190W, 24 V input supply, 50kHz and 75% duty cycle. The proposed switched inductor Sepic (SI-SEPIC) converter topologies are simulated in MATLAB/SIMULINK. Both theoretical analysis and simulation results are provided to verify the main characteristics.

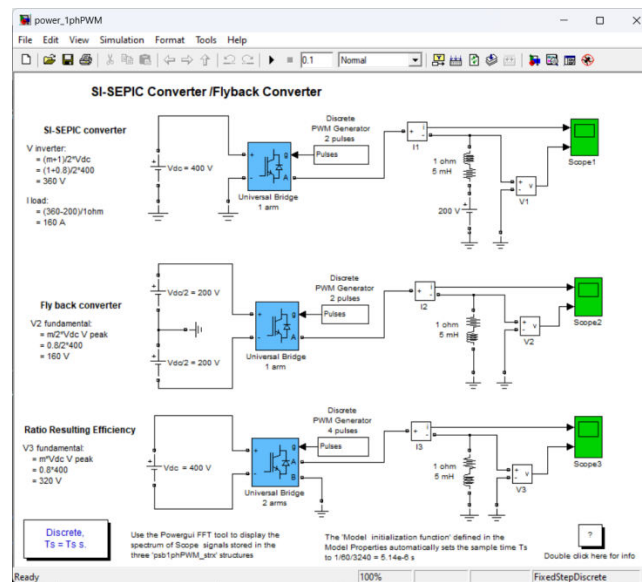
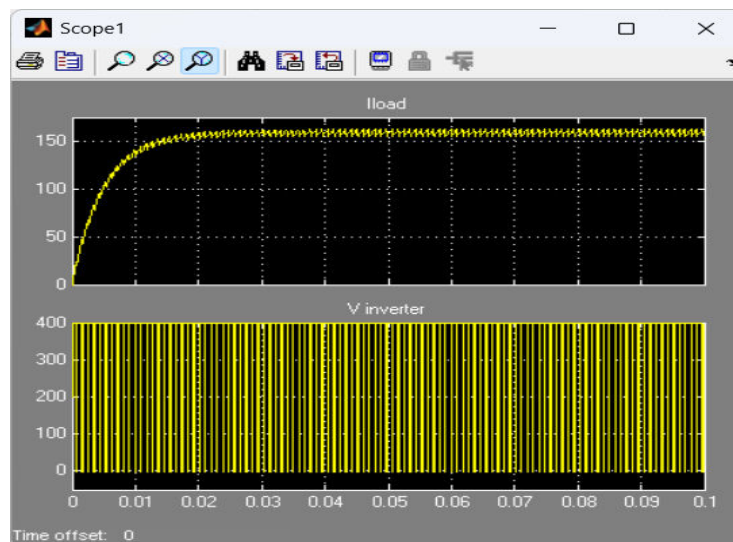
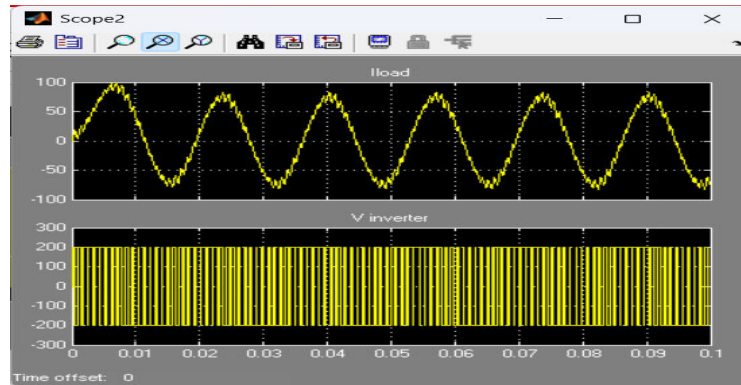


Fig - SI-SEPIC Converter /Flyback Converter

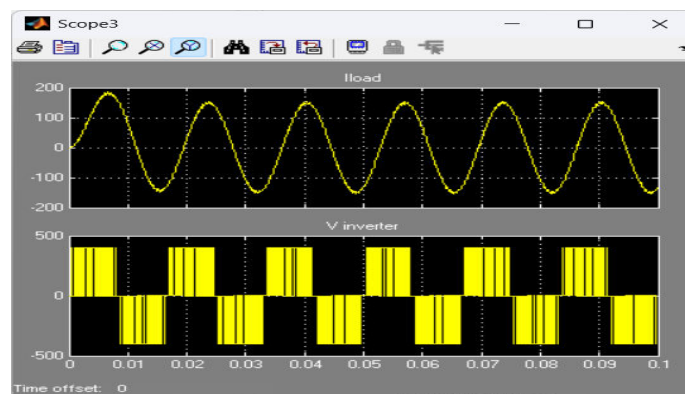
MODE-1



MODE-2



MODE-3



V. CONCLUSION

The cascaded SI-SEPIC and flyback converter is designed for EV application. Due to SI-SEPIC configuration at the input, high voltage gain is achieved as compared to conventional SEPIC converter, it also operates at reduced duty ratio to achieve an output voltage of 300V. This leads to low THD as per IEC standard, and thereby improving the PF (Power Factor) and efficiency of the converter. Two control techniques i.e. PWM and SPWM controller techniques are designed for the adequate performance of the converter and the obtained results are compared. As a way forward the proposed converter can be used for multiple battery rating, variable load and can be used with different sort of motor used in EV application.

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