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Designand Controlled for Bridgeless Zeta-Luo Converter for EV Charging

Vishal Kardak[1], Roshan Bodke[2], Chandan Dhake[3], Umesh Kalyankar[4]

Abstract: ***Thewidespreadadoptionofelectricvehicles(EVs)hasnecessitatedthedevelopmentofefficientand reliable charging infrastructure. Conventional EV chargers often employ bridge rectifiers, which can lead to significant conduction losses due to the presence of high-voltage diodes. To address this limitation, a novel EV charger based on a bridgeless (BL) isolated Zeta-Luo converter with built-in power factor (PF) preregulation capability at the supply side has been proposed. The BL isolated Zeta-Luo converter is a combination ofa Zeta converter and aLuo converter, each operating during alternatehalves of the supply voltage cycle. This approach eliminates the need for bridge rectifiers, reducing conduction losses and improving overall efficiency. Additionally, the shared output inductors of the Zeta and Luo converters furthercontributeto the compact sizeand lightweight design ofthecharger.Thebuilt-in PFPreregulation capability ensures that the charger operates with a near-unity power factor, minimizing reactive power consumption and improving grid stability. This is achieved by regulating the input current waveform to closely match the input voltage waveform. The proposed EV charger offers several advantages over conventional chargers, including:***

The BL topology and shared output inductors significantly reduce semiconductor losses, leading to improved efficiency. The built-in PF Preregulation capability ensures near-unity power factor operation, minimizing reactive power consumption and improving grid stability. The elimination of bridge rectifiers and the sharing of output inductors result in a compact and lightweight charger design. Enhanced performance under sudden voltage variations: The proposed charger exhibits robust performance under sudden line voltage fluctuations, ensuring reliable EV charging even during unstable grid conditions. The Bridgeless Isolated Zeta–Luo Converter-Based EV Charger With PF Preregulation presents a promising solutionforefficientandreliableEVcharging.Itscombinationofhighefficiency,improvedpowerfactor, reduced size, and enhanced performance under voltage variations makes it an attractive choice for future EV charging infrastructure.

Keywords: Power FactorCorrection,Zeta-LuoConverter, FLCController,EVCharging,DCM

Abbreviations

BEV	Battery-basedElectricVehicle Power
PQ	Quality
DBR	Diode Bridge Rectifier Power
PFP	Factor Preregulator
EMI	ElectromagneticInterference
PFC	Power Factor Correction
EV	Electric Vehicle
CC	ConstantCurrent
CV	ConstantVoltage
THD	Total Harmonic Distortion
IIC	Inductor-InductorCapacitor
MOSFET	Metal–oxide–semiconductorfield-effecttransistor Pulse
PWM HFT	Width Modulation
SoC	HighFrequency Transformer
	Stateof Charge

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Symbols and Notations

$I_{dc_{ref}}$	Referencecurrent
$V_{dc_{re}}$ f	ReferenceVoltage
V_{spk}	rmssource voltage
ω	Supply Frequency
Δ	Depictstherippleinconverterdc-link voltage
θ	Angleby linecurrentleads or lags
Υ	Voltage Ripple
K_{pv}	ProportionalgainconstantforVoltage
K_{iv}	Integralgain constantfor Voltage
V_{dc}	Output DC Voltage
I_{dc}	Output DC Current

C_f	FilterCapacitor
C_{dc}	CapacitorDC Voltage
L_f	Filter Inductor
V_s	Supply Voltage
L_{m1}	MagnetizingInductance
S_1	Switch1
S_2	Switch2
I_s	Supply Current
I_{lo}	InductorCurrent
F_{cr}	FilterCut-Frequency

I. INTRODUCTION OF ZETA AND LUO CONVERTER

A. Introduction

Introduction Similar to the SEPIC DC/DC converter topology, the ZETA converter topologyprovidesa positiveoutputvoltagefromaninputvoltagethatvariesaboveand belowthe output voltage. The ZETA converter also needs two inductors and a series capacitor, sometimes called a flying capacitor. Unlike the SEPIC converter, which is configured with a standard boost converter,theZETAconverterisconfiguredfromabuck controllerthatdrivesahigh-sidePMOS FET.TheZETA converterisanotheroptionforregulatinganunregulatedinput-powersupply,like a low-cost wall wart. To minimize board space, a coupled inductor can be used. This article explains howto design a ZETAconverter running in continuous-conduction mode(CCM)with a coupled inductor.

B. Circuit Diagram of Zeta Converter

The below figure shows the schematic diagram of a zeta converter. It consists of two inductors, a capacitor, and a diode. The circuit of the zeta converter is almost similar to a single- ended primary-inductor converter (SEPIC) except in the place of the diode in SEPIC, there is an inductorinthezetaconverter,andintheplaceofthesecondinductorinSEPIC,thereisadiodein zeta converter.

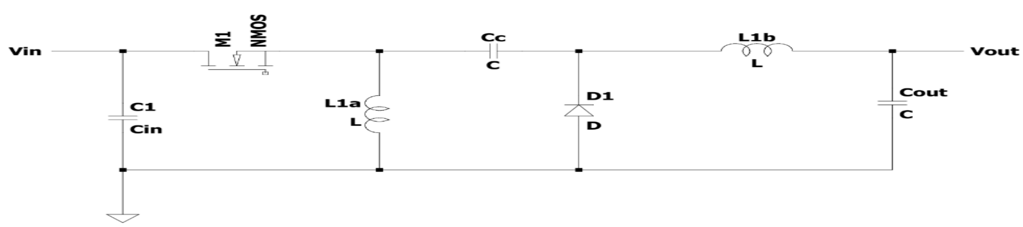

Fig.1.1Circuitdiagram ofZETA converter

ThecapacitorC1actsasthebridgebetweentheinputandoutputsidesoftheconverter.Italsoisolates input andoutputsides fromeachother. Generally,atransistor (MOSFET or IGBTor BJT) isusedas the switch in dc-to-dc converters, due to low power loss, higher input impedance, and simple driver circuitry MOSFETs are mostly used.
TheMOSFETswitchingiscontrolledbyPWMpulsesappliedatthegateterminaland feedback taken from the output so that the desired regulated output will be obtained.

C. Working of Zeta Converter

Figure 1.1 shows a simple circuit diagram of a ZETA converter, consisting of an input capacitor, CIN; an output capacitor, COUT; coupled inductors L1a and L1b; an AC coupling capacitor, CC; a power PMOS FET, Q1; and a diode, D1. Figure 2 shows the ZETA converter operating in CCM when Q1 is on and when Q1 is off.
Tounderstandthevoltagesatthevariouscircuitnodes,itisimportanttoanalyzethecircuit at DC when both switches are off and not switching. Capacitor CCwill be in parallel with COUT, soCC ischargedtotheoutputvoltage,VOUT,duringsteady-stateCCM.Figure2showsthevoltages across L1a and L1b during CCM operation.

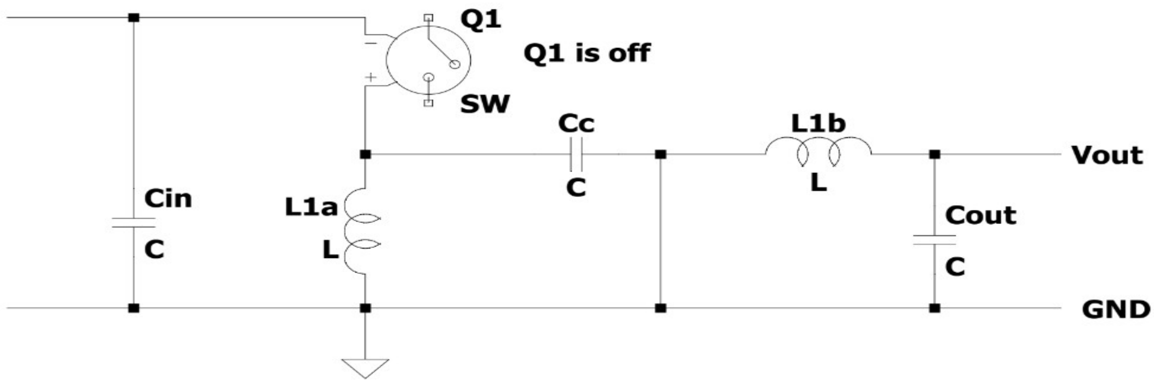

Figure.1.2ZETAconverterduringCCMoperation,whenQ1isOff

Mode1 [$t_0 - t_1$]: When $Q_1$is off, the voltage across L_{1b}must be VOUT since it is in parallel with COUT. Since COUT is charged to VOUT, the voltage across $Q_1$when$Q_1$is off is VIN + VOUT; therefore, the voltage across $L_{1a}$is – VOUT relative to the drain of Q_1. When $Q_1$is on, capacitor CC, charged to VOUT, is connected in series with L_{1b}; so the voltage across L1b is + VIN, and diodeD_1sees VIN + VOUT. The currents flowing through various circuit components are shown in Figure.1.2.

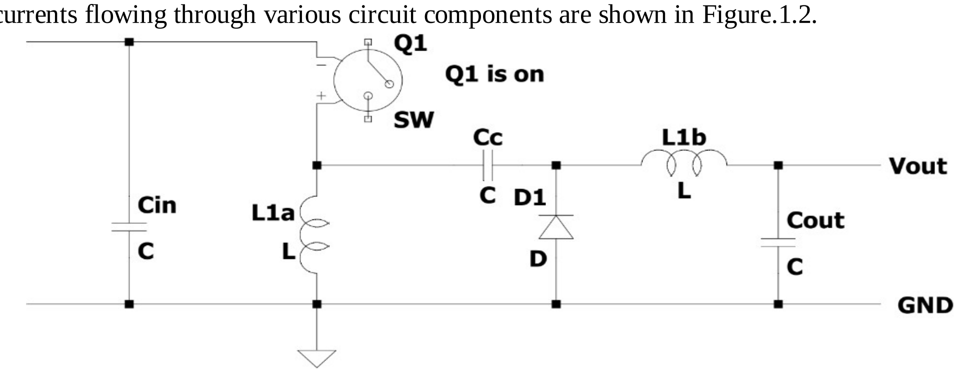

Figure1.3ZETAconverterduring CCM operation,whenQ1is on

Mode2[$t_1 - t_2$]:WhenQ_1ison,energyfromtheinputsupplyisbeingstoredinL_{1a},L_{1b},and
CC. L_{1b}also provides IOUT. When Q_1turns off, L_{1a}'s current continues to flow from current provided by CC, and L_{1b}again provides IOUT. The currents flowing through various circuit components are shown in Figure 1.3.

D. Introduction of LUO Converter(boostconverter)

TheIsolatedDC-DCconvertersarecommonlyutilizedforhighpowerapplicationbecause of high efficiency, simple control, steady state input current, high voltage gain and lower order voltage ripple contents. In recent days, many researchers have focussed on Luo converter due to high output voltage gain and continuous input current operation. This proposed converter is developed from Super lift elementary Luo converter topology. The PV application also requires highgainconverterswithoptimize dalgorithmsfort rackingmaximumpowerfrominputside.Theboostconvertersarewidelyusedinresearches.Theoutputvoltagegainisverylowforaboostand buck-boost converter topologies and it also has higher order ripple contents in its output voltage and thus the buck-boost type converter suffers from output voltage polarity problem. This drawback reduces the effectiveness of the converter. Buck-boost converter voltage is a non- isolated voltage. These drawbacks are overcome in . The isolated boost integrated converter is developed even though the gain is very less for this converter. To reduce the leakage reactance problem, magnetically coupled DC-DC converter is developed. This converter having high efficiency, the different shaped inductors reduce the leakage reactance problem. Finally Luo converter is developed to achieve high output gain with lifting constant all the existing issues are overcome. The proposed hybrid-lift DC-DC converter increases the output voltage gain with less ripple content. The PI controller achieves steady state voltage operation.

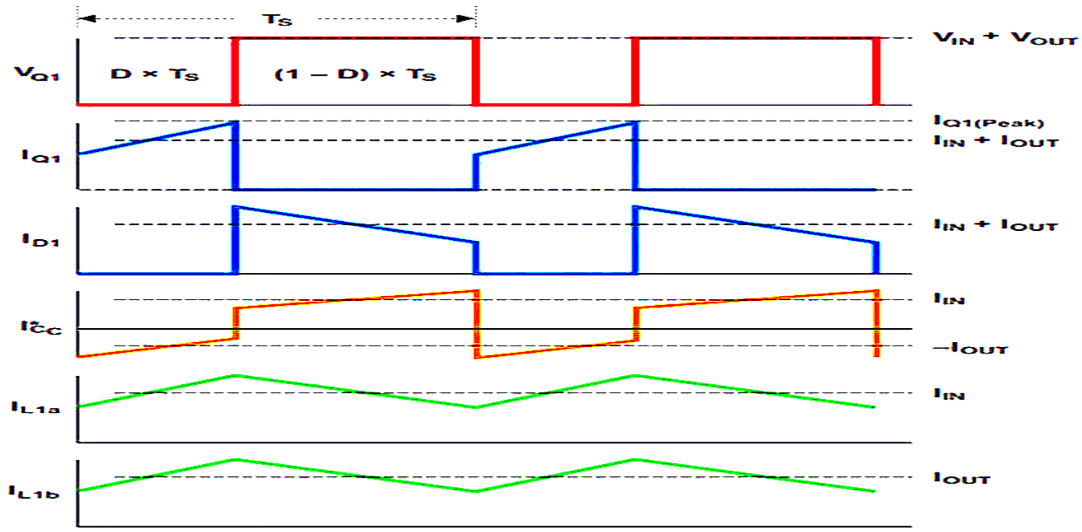

Fig.1.3,ZETAconverter'scomponentcurrentsduringCCM

E. Introduction of LUO Converter(boostconverter)

TheIsolatedDC-DCconvertersarecommonlyutilizedforhighpowerapplicationbecause of high efficiency, simple control, steady state input current, high voltage gain and lower order voltage ripple contents. In recent days, many researchers have focussed on Luo converter due to high output voltage gain and continuous input current operation. This proposed converter is developed from Super lift elementary Luo converter topology. The PV application also requires highgainconverterswith optimizedalgorithms fortrackingmaximumpowerfrominputside.The boostconvertersarewidelyusedinresearches.Theoutputvoltagegainisverylowforaboostand buck-boost converter topologies and it also has higher order ripple contents in its output voltage and thus the buck-boost type converter suffers from output voltage polarity problem. This drawback reduces the effectiveness of the converter. Buck-boost converter voltage is a non- isolated voltage. These drawbacks are overcome in . The isolated boost integrated converter is developed even though the gain is very less for this converter. To reduce the leakage reactance problem, magnetically coupled DC-DC converter is developed. This converter having high efficiency, the different shaped inductors reduce the leakage reactance problem. Finally Luo converter isdevelopedtoachievehighoutputgainwithliftingconstantalltheexistingissuesare overcome.

The proposed hybrid-lift DC-DC converter increases the output voltage gain with less ripple content. The PI controller achieves steady state voltage operation.

F. Working of Luo Converter

ToanalysetheoperationoftheLuoconverter,thecircuitcanbedividedintotwomodes. When the switch is ON, the inductor $L_1$is charged by the supply voltage E. At the same time, the inductor L_2absorbs the energy from source and the capacitor C_1.

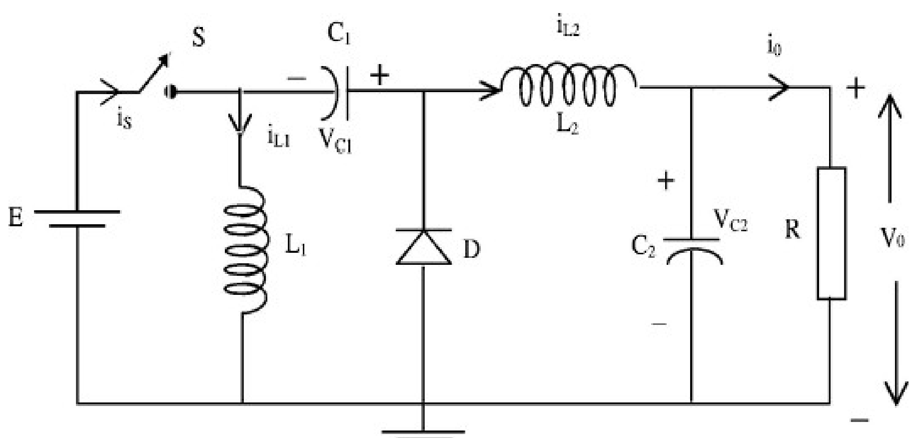

Figure.1.4,Circuit diagramofZETAconverter

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The load is supplied by the capacitor C_2. The equivalent circuit of Luo converter in mode 1 operation is shown in Figure.1.4. During switch is in OFF state, and hence, the current is drawn from the source becomes zero, as shown in Fig.1.5. Current i_{l2}flows through the freewheeling diode to charge the capacitor C_1. Current i_{l2}flows throughC_2–R circuit and the freewheeling diode$D$tokeepitselfcontinuous.Ifaddingadditionalfiltercomponentslikeinductorandcapacitor to reduce the harmonic levels of the output voltage.

Mode1[t_0 $-t_1$]:whentheswitchisON,theinductorL1ischargedbythesupplyvoltageE.At the same time, the inductor L2 absorbs the energy from source and the capacitor C1. The load is suppliedbythecapacitorC2.TheequivalentcircuitofLuoconverterinmode1operationisshown in Figure.1.5

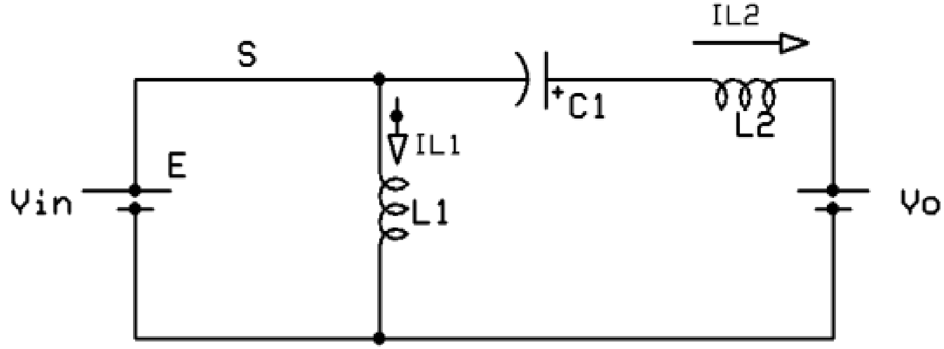

Fig.1.5,CircuitDiagram forMode1

Mode 2 [$t_1 - t_2$]: switch is in OFF state, and hence, the current is drawn from the source becomes zero, as shown in (b). Current iL1 flows through the freewheeling diode to charge the capacitorC1.CurrentiL2flowsthroughC2–RcircuitandthefreewheelingdiodeDtokeepitself continuous operation is shown in Figure.1.6.

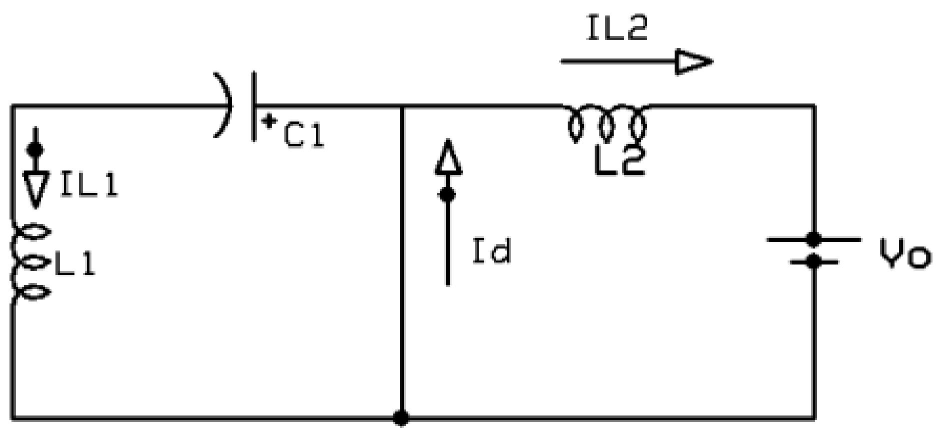

Figure.1.6,CircuitDiagramforMode2

In discontinuous conduction mode, output should be in the form of discontinuous. In this modediodeisnotpresentandinductor dischargethroughV0andL2.TheoutputstageoftheLuo buck converter is comprised of an inductor and capacitor. The output stages stores and delivers energytotheload,andsmoothsouttheswitchnodevoltagetoproduceaconstantoutputvoltage. Inductorselectiondirectly influencestheamountofcurrentrippleseenontheinductorcurrent,as well as the current capability of the buck converter itself. Inductors vary from manufacturer to manufacturerinbothmaterialandvalue,andtypicallyhaveatoleranceof20%.Inductorshavean inherent DC resistance (known as the DCR) that impacts the performance of the output stage. MinimizingtheDCRimprovestheoverall performanceoftheconverter.Forthatapplicationit requiresahighloadcurrent,itisrecommendedtoselectaninductorwithalowDCR.TheDCRis smaller for lower inductor values, but there is a trade–off between inductance and ripple current; the lower the inductance, the higher the ripple current through the inductor.
Aminimuminductancemustbemetinordertomeettheripplecurrentrequirementsofthe specific application circuit.

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The output capacitance directly affects the output voltage of the converter and the response time of the output feedback loop, also the amount of output voltage overshoot that occurs during changes in load current. A ripple voltage exists on the DC output as the current through the inductor and capacitor increases and decreases. Increasing the value of output capacitance value reduces the amount of voltage ripple present in the circuit.

However, there is a trade-off between capacitance and the output response. Increasing the capacitance reduces the output voltage ripple and output voltage overshoot, but increases the response time it takes output voltage feedback loop to respond to changes in load. Therefore, a minimum capacitance must be considered, in order to reduce the ripple voltage and voltage overshoot requirements of the converter, while maintaining a feedback loop that can respond quickly enough to load changes. Capacitors also have a parasitic series resistance, known as the equivalent series resistance (ESR). The steady state capacitor value is 0A shown in figure 1.7.

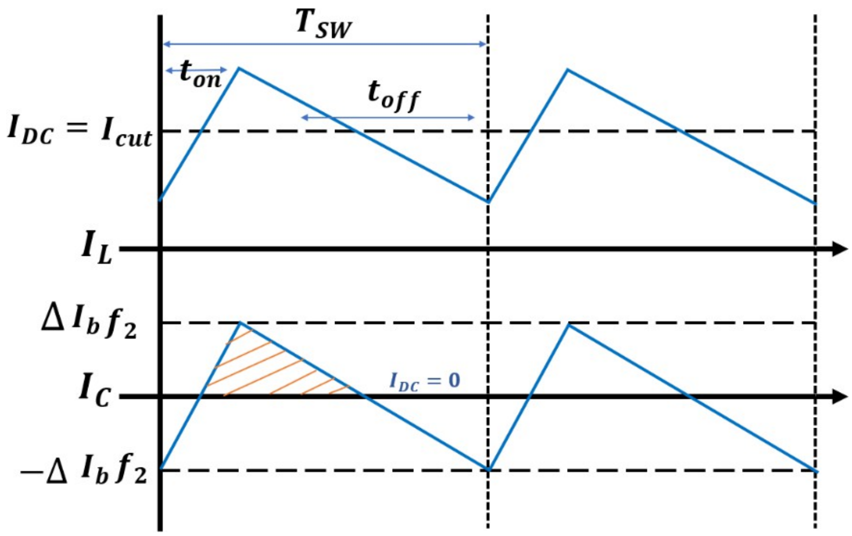

Fig.1.7.ZETAconverter'scomponentcurrentsduring DCM

G. Summary

The SEPIC converter, the ZETA converter is another converter topology to provide a regulatedoutputvoltagefromaninputvoltagethatvariesaboveandbelowtheoutputvoltage.ThebenefitsoftheZETAconverterovertheSEPIC converterincludeloweroutputvoltagerippleandeasiercompensation.Thedrawbacksaretherequirementsforahigherinputvoltageripple,amuch larger flying capacitor, and a buck controller (like the TPS40200) capable of driving a high-side PMOS.

The two-stage approach secures a minimum totalstress on the circuit components. Further research in PFC systems should be directed towards optimizing the PFC stage and/or the DC/DC stage. It is misunderstood that reducing the number of stages and/or processing less power automaticallyachieveshigherefficiency.Properdesignandproperpowerprocessingachievehigh efficiency.Ingeneral,lowcomponentstresscanbetranslatedintohighefficiency,smallphysical sizeandlowcost.Inthelowpowerrangesomeofthealternativesolutionscanhaveanadvantage in cost compared to the two-stage solution but the efficiency will be sacrificed.

ThispaperdiscussesthecontroloftheoutputvoltageofaDCstep-upconverterbyvarying the input voltage from a single PV source with the help of fuzzy logic. The investigation was conducted through simulation and implementation, with the variation of PV input and load being tested. Research has discovered that the Zeta Converter can increase the output voltage to 24V with a minimum input voltage of 17V while maintaining an average efficiency of 85.83 percent during the simulation and 71.9 percent during implementation. With a variety of input voltages, the fuzzy algorithm can maintain a constant output voltage of 24V. Fuzzy requires an average response time of 3 seconds to increase the voltage and 2 seconds to decrease the voltage on average.

II. SYSTEM OVERVIEW

A. Introduction

The bridgeless isolated Zeta–Luo converter with PF Preregulation is a two-stage converter that consists of a PF Preregulation stage and a bridgeless isolated Zeta–Luo converter stage.

The PF Preregulation stage draws a sinusoidal current from the AC mains and converts it to a high- voltage DC voltage. The bridgeless isolated Zeta–Luo converter stage then converts this high- voltage DC voltage to a low-voltage DC voltage that is suitable for charging the EV battery.

ThePFpreregulationstagetypicallyconsistsofaboostconverteroraViennarectifier.Theboostconverterisamorecommonchoice,asitissimplertoimplementandhasahigherefficiency. The Vienna rectifier is a more complex circuit, but it can achieve a higher power factor.

The bridgeless isolated Zeta–Luo converter stage is a combination of the Zeta and Luo converters. It has the advantages of both converters, including a wide input voltage range, high efficiency, and low output voltage ripple.

The bridgeless isolated Zeta–Luo converter-based EV charger with PF preregulation is a complex circuit, but it offers a number of advantages over other conventional EV charger topologies. It has a high efficiency, a wide input voltage range, and a low output voltage ripple. Additionally, the PF preregulation stage ensures that the charger draws a sinusoidal current from the AC mains, even under varying load conditions.

B. Literature Review

Anewelectricvehicle(EV)chargerbasedon abridgeless(BL)isolatedZeta–Luoconverterwith built-in power factor (PF) preregulation capability at the supply side. This configuration is a combination of Zeta and Luo converters, which are designed to work during individual halves of supply voltage. This gives additional benefits of higher efficiency than the previously developed converters on the account of sharing [1].

Stateoftheartandfuturetrendsforhighpowerconductiveonboardchargers(OBCs)forelectricvehicles.Toprovideaglobalcontext,asummaryofglobalchargingstandardsandelectricvehicle (EV) related trends are presented, which demonstrates momentum toward the OBCs with higher power rating [2].

Power electronics is an enabling technology for the development of these environmentally friendliervehicle sandimplementingtheadvancedelectricalarchitecturestomeetthedemandsfor increased electric loads. In this paper, a brief review of the current trends and future vehicle strategies and the function of power electronic subsystems are described [3].

The impact of electric vehicles on power quality in electric distribution system is evaluated. Voltage deviations such as under/over voltage and voltage imbalance are probabilistically quantified using Monte Carlo. Moreover, distribution transformers overload and unbalance are assessed for different vehicle types (i.e., plug-in hybrid and battery electric), different vehicle penetration (up to 50%) while considering level 1 and level 2 charging [4].

Thediscussion concerning the use of single-stage contratwo-stage PFC solutions has been going onforthelastdec adeanditcontinues.Thepurposeofthispaperistodirectthefocusbackonhow the power is processed and not so much as to the number of stages or the amount of power processed. The performance of the basic DC/DC topologies is reviewed with focus on the component stress [5].

This converter is designed to operate with adjustable output voltage so that it can operate in two distinct operation modes, depending on the input and output voltages. Therefore, small-signal state-space average models are obtained for the converter operating in step-down and step-up operation modes, and analysis and design of the digital control system are included for different operating points [6].

This paper presents a topology survey evaluating topologies for use in front end ac-dc converters forPHEVbatterychargers.Thetopologysurveyisfocusedonseveralboostpowerfactorcorrected converters, which offer high efficiency, high power factor, high density, and low cost. Experimental results are presented and interpreted for five prototype converters, converting universal ac input voltage to 400 V dc [7].

Charger systems are categorized into off-board and on-board types with unidirectional or bidirectional power flow. Unidirectional charging limits hardware requirements and simplifies interconnection issues. Bidirectional charging supports battery energy injection back to the grid. Typicalon-boardchargersrestrictpowerbecauseofweight,space,andcostconstraints.Theycan be integrated with the electric drive to avoid these problems. The availability of charging infrastructurereduceson-boardenergystoragerequirementsandcosts.On-boardchargersystems can beconductiveorinductive.Anoff-boardchargercan be designedforhigh chargingratesand islessconstrainedbysizeandweight.Level1(convenience),Level2(primary),andLevel3(fast) powerlevelsarediscussed.Futureaspectssuchasroadbedchargingarepresented.Variouspower level chargers and infrastructure configurations are presented, compared, and evaluated based on amount of power, charging time and location, cost, equipment, and other factors [8].

In this article, the research of battery chargers in boost charge mode is performed using a mathematical model in EMTP- RV program. During research the root-mean-square value of current ripples were defined while different types of batteries supplying.

The effect of battery chargers' filters, battery internal resistance and permanent load current on current ripples is considered. It is shown, that thyristor battery chargers without filters is fall short of normative current ripples requirements, that can lead to battery service life decrease and filter use doesn't always allow to solve this problem [9].

Solid-state switch mode AC-DC converters having high-frequency transformer isolation are developedinbuck,boost,andbuck-boostconfigurationswithimprovedpowerqualityintermsof reduced total harmonic distortion (THD) of input current, power-factor correction (PFC) at AC mains and precisely regulated and isolated DC output voltage feeding to loads from few Watts to several kW. This paper presents a comprehensive study on state of art of power factor corrected single-phase AC-DC converters configurations, control strategies, selection of components and designconsiderations, performanceevaluation, powerqualityconsiderations,selectioncriteriaand potential applications, latest trends, and future developments. Simulation results as well as comparative performance are presented and discussed for most of the proposed topologies [11].

A bridgeless buck power factor correction rectifier that substantially improves efficiency at low line of the universal-line range is introduced. By eliminating input bridge diodes, the proposed rectifiers efficiency is furtherimproved. Moreover, therectifier doublesits output voltage, which extendsuseableenergyofthebulkcapacitorafteradropoutofthelinevoltage.Theoperationand performance of the proposed circuit was verified on a 700-W, universal-line experimental prototype operating at 65 kHz. The measured efficiencies at 50% load from 115 and 230 V line arebothcloseto96.4%. Theefficiencydifference betweenlowlineand highlineislessthan0.5% at full load. A second-stage half-bridge converter was also included to show that the combined power stages easily meet Climate Saver Computing Initiative Gold Standard [12].

This paper proposes a novel single-phase single-stage ac-dc converter with high-frequency isolation and power factor correction. Unlike the two-stage ac-dc converters, the high-frequency pulsating voltage is obtained directly from the power factor correction semi stage and is applied directly to the dc-dc semi stage. The proposed topology is designed to be operated in the continuous conduction mode (CCM), and therefore, there is no need for additional input filter. In addition, the interleaving operation helps reducing the current stress and gets a better electro- magneticinterferenceperformance. Moreover,allofthepower switchesintheproposedtopology can achieve soft-switching commutation. Furthermore, the intermediate dc-link capacitor is no longerdirectlyconnectedtothedc-dcstageandthecapacitancecanbereducedgreatly;therefore, the bulk capacitor is replaced by a film capacitor. Frequency characteristics and time-domain analysis of the LLC resonant tank is presented in this paper to analyse the characteristics of the proposedconverter.Finally,aprototypethatconvertsuniversalinputvoltagerangingfrom110to 220 V into 400-V dc output was built and tested to verify the analysis [13].

A new method for deriving isolated buck-boost (IBB) converter with single-stage power conversionisproposedinthispaperandnove lIBBconvertersbasedonhigh-frequencybridgeless- interleaved boost rectifiers are presented. The semiconductors, conduction losses, and switching lossesarereducedsignificantlybyintegratingtheinterleavedboostconvertersintothefull-bridge diode-rectifier.Varioushighfrequencybridgelessboostrectifiersareharvestedbasedondifferenttypesofinterleavedboostconverters,includingthe conventionalboostconverterandhighstepupboostconverterswithvoltagemultiplier,andcoupledinductor.ThefullbridgeIBBconverterwith voltage multiplier is analyzed in detail. The voltage multiplier helps to enhance the voltage gain and reduce the voltage stresses of the semiconductors in the rectification circuit [14].

This paper proposes a soft-switched interleaved boost converter with minimal conduction loss increment and removed reverse-recovery problem. The soft-switching operation is enabled by a soft-switching cell composed of passive components in which an auxiliary coupled inductor and a dc-link capacitor are connected between the switch legs of the interleaved boost modules and output stage. Every MOSFET switch of the proposed boost converter operates with zero-voltage switching turn- on using the coupled inductor current. Consequently, the switching loss of the proposed interleaved boost converter is greatly reduced. In addition, the reduced circulating current in the auxiliary circuit minimizes the increment of the conduction loss. The proposed soft-switched interleaved boost converter operation is verified with 500-W experimental results [15].

Asakeycomponentofaplug-inhybridelectricvehicle(PHEV)chargersystem,thefront-endac- dc converter must achieve high efficiency and power density. This paper presents a topology surveyevaluatingtopologiesforuseinfrontendac-dcconvertersforPHEV batterychargers.The topology survey is focused on several boost power factor corrected converters, which offer high efficiency, high power factor, high density, and low cost. Experimental results are presented and interpreted for five prototype converters, converting universal ac input voltage to 400 V dc [16].

This paper presents the dynamic modeling and digital control of a single-stage isolated current rectifier with power factor correction based on the integration of full-bridge and flyback converters. This converter is designed to operate with adjustable output voltage so that it can operate in two distinct operation modes, depending on the input and output voltages.

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Therefore, small-signalstate-spaceaveragemodelsareobtainedfortheconverteroperatinginstep-downand step-up operation modes, and analysis and design of the digital control system are included for different operating points. Experimental results based on a 3-kW prototype are presented to validate the proposed control system under distinct conditions [17].

C. Summary

The literature review on the design and control circuit for Zeta Luo converters in electric vehicle battery chargers reveals a significant focus on enhancing efficiency, reducing size, and improvingcontrolstrategies. Studiesemphasize theimportance ofoptimaldesignparameters,such as component selection, topology modifications, and control techniques, to achieve high efficiency, fast charging, and compatibility with varying battery technologies. Challenges, includinghigh-frequencyswitching, electromagneticinterference,andthermalmanagement,have been addressed through innovative circuit topologies and control algorithms. Despite advancements,furtherresearchisneededtooptimizeperformance,increasepowerdensity,and ensure robustness in real-world applications for efficient and reliable electric vehicle charging systems.Thisbriefintroducesanisolatedtwo-switchZetadc–dcconverter,alongwiththesteady- state analysis and experimentation.

The high transistor voltage stress due to the ringing caused by the resonance of the transformer leakage inductance and the transistor output capacitance is a major drawback in the conventional isolated Zeta converter. With the incorporation of an additional transistor and two clamping diodes on the primary side of the transformer of the isolated Zeta converter, an isolated two transistor Zeta converter is proposed. In the proposed converter, the voltage stress of both transistors is reduced to the dc input voltage. Experimental results from a 10-V/30-W 100-kHz laboratoryprototypearepresented tovalidatethetheoreticalanalysis. Thetwotransistorsplusthe clamping diodes on the primary side of the transformer provide a simple mechanism to limit the switch overvoltage, which occurs in the isolated single-transistor Zeta converter. The theoretical analysis has been verified by experimental results. The clamping of the switch over voltages has been achieved. The power transistors have been turned on under reduced voltage stresses. The analysis and experimental results provide a basic understanding of the converter behaviour. The proposed isolated two-switch Zeta converter is a simple topology and can be of high practical value for various industrial applications such as universal input adapters/charges for cell phones, laptop, and computers; and power supplies for telecommunication equipment, digital video disc players, and light emitting diode displays. Future work constitutes the modelling

III. SYSTEM DESCRIPTION

A. Introduction

Toensurereducedelectromagneticinterferenceatinputandtoobtainlowswitchingdevice losses,asingle-stageresonantconverter is discussedfor EV. However,theneedforfourswitches to integrate the operation of boost and full bridge LLC converter results into a complex design process of the PFC converter, which is not recommended at sudden varying voltages. Another boost-fed full-bridge converter for EV chargers, which has the obvious demerits with increased componentsandcircuit complexity,aswellasacomplexcontrolalgorithmneedstobedeveloped for four gate drivers. Therefore, to retain the benefits of improved power density and high efficiency, as well as to providesimple control, various off-board solutions forunidirectional EV chargers.

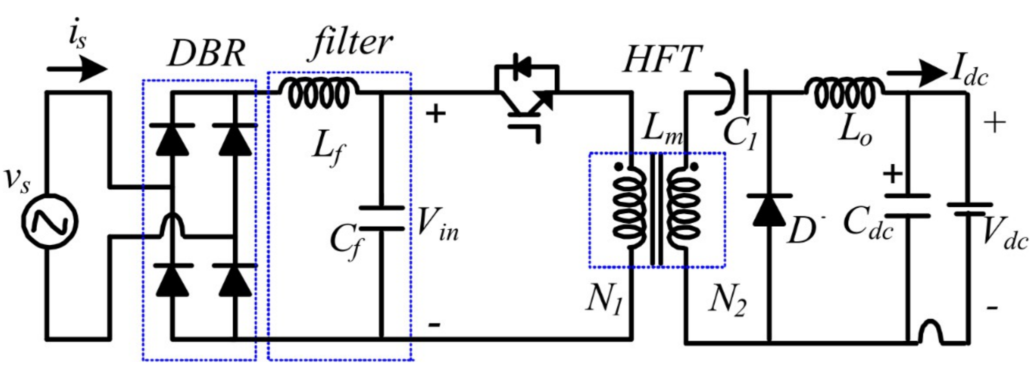

Fig.3.1.CircuitconfigurationofIsolatedZeta converter

However, a single-stage isolated PFC converter with input DBR comes out to be lossy, whichresultsintopoorcharging efficiencyduetotheincreasedconductionloss.

Theunidirectional battery chargers incorporate the popular boost PF preregulator for the intrinsic PFC operation. However, at high power, conventional buck and boost converters are found unsuitable, as the current wave-shaping characteristic is not effective, at zero crossing in the buck converter. Moreover, the boost converter shows restricted change in duty cycle over the fluctuation in line voltage. This restriction in the duty cycle is avoided using buck–boost converters, for PF preregulationatthechargermains, asthedutycyclemayvaryeffectivelyoverthecompleterange of line voltages. A detail review and design guidelines for buck–boost-based high-frequency isolatedimprovedPQconverters(IPQCs)arepresentedintheliterature.Thedifferentbuck–boost based configurationssuchasflyback,single-endedprimaryinductorconverter(SEPIC),Cuk,Luo and Zeta converters for PF preregulation in several single-phase applications.

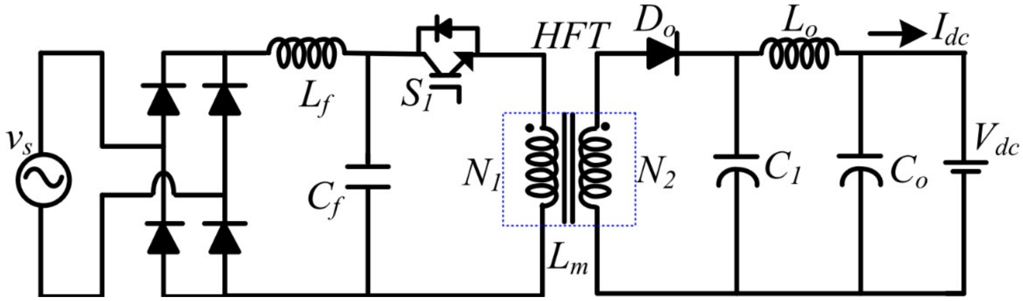

Fig.3.2.CircuitconfigurationofIsolatedLuoconverter

The disadvantage of pulsating output current and the large size of filters to minimize the output charge ripple in the single-stage isolated SEPIC converter makes it unsuitable for the PF preregulatedcharger. TheCukconverter isquitepopular inthisrangeasreducedrippleatboththe input and output end is achieved. However, it requires series capacitor with high rms current for operation at increased rating. The Zeta and Luo converters both offer excellent PQ improvement features, good light load regulation, and the advantage of low ripple in charging current, as well, when used in combination.

The configuration of this BL isolated Zeta–Luo converter-based vehicle charger is obtain by the integration of BL isolated Zeta and Luoconverters, which conduct in two separate halfcycles, independently. The operation of the BL converter is achieved in the discontinuous mode ofoperationtoprovidePFpre-regulationattheratedandoverwiderangeofvaryingmains voltages. During the operation of the Zeta converter, the semiconductor switch S1, transformer magnetizinginductanceL_{m1},intermediatecapacitorC_1, andoutputdiodeDo1conductduringpositivehalfofthesupplycycle. However,theoperationoftheLuoconverterduringthenegativehalf of the supply is assisted with the semiconductor switch S2, transformer magnetizing inductance L_{m2}, intermediate capacitor C_2, and output diode Do2. The theoretical analysis during the steady-state operation of this BL isolated converter is detailed as follows

To improve the charger efficiency, many bridgeless (BL) PFC converter topologies with isolation are reported in the literature. This reduces the semiconductor losses as several diodes, which conduct over a switching cycle, are reduced to half. The circuit configuration of conventionalisolatedZetaandLuoconvertersisshowninFig.3.1and3.2.Therefore,basedon abovementioned DBR-based topologies, an EV charger with an integrated BL isolated Zeta–Luo configuration, as shown in Fig.3.3, is developed as per the design expressions, in this work. The charging of a 48 V, 100 Ah EV battery is identified in the constant current and constant voltage (CC–CV) modes using a cascaded proportional-integral (PI) controller.

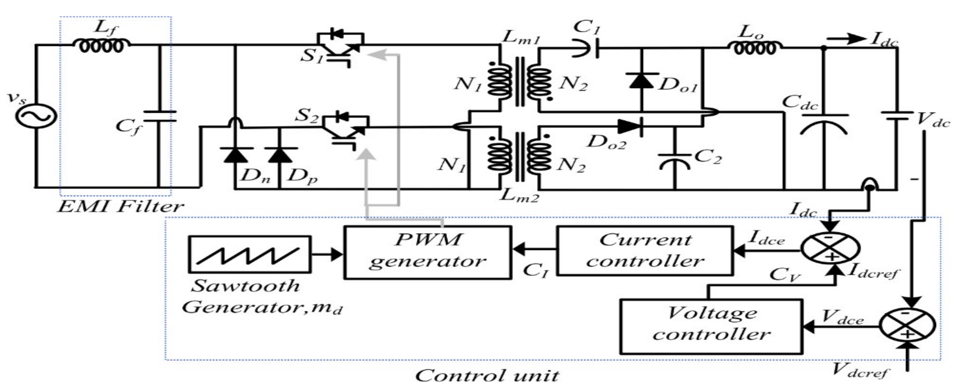

Fig.3.3CircuitconfigurationofBLisolatedZeta–Luoconverter-basedcharger.

ThisnewBLconverterisdesignedtooperateindependentlyduringtherespectivepositiveandnegativesupplycyclesineithertheZetaorLuomode.Thisgivestheadditionalbenefitsofhigherefficiencythanthepreviouslydevelopedconvertersontheaccountofsharingtheoutputinductors for both converters. The topology offers the advantage of reduced number of components as compared to other BL configurations due to the integration of two different converters. The significant features and contribution of this charger configuration are listed as follows.

1) Thenumberofoutput inductors are reduced dueto integration ofZeta–Luo convertersin two half cycles. This gives significant reduction in the size of the charger.
2) Overaswitchingcycle,thecurrentconductionisseentobeviareducednumberofcomponents and devices; which, comparatively, gives the improvement in efficiency.
3) The value of the magnetizing inductance of this isolated converter is selected such as the converter remains in the discontinuous conduction mode (DCM), which is beneficial for the charger with the reduced size and low cost.
4) The control of the PFC converter is easy to implement as similar pulses are given to both switches in each line cycle. The robust performance of this new BL isolated EV charger is foundsatisfactoryduring thechargingoperation at thesteady stateas well as overthechange in line voltage and loads. The performance indices at utility such as mains PF, DPF, supply current THD, are seen to comply with the recommended PQ regulations.

B. Operation of BL Isolated Converter

Three different operating modes and associated key operation of this isolated converter, in Zeta and Luo modes for the corresponding supply halves, are illustrated as follows.

Mode-I [t_0–t_1]: During this mode, gate pulse to switch S1 is given at instant to. The magnetizing current in the inductance Lm1 builds up linearly, as it stores the energy from the source via the line diode Dp. The voltage across the energy transfer capacitor C1 starts decreasing as current findsapaththroughtheoutputinductorLo1atthesecondaryside,asshowninFig.3.1.Theoutput diodeDo1isseentobeinthenonconductingstateduringthisinterval.Thismodeendsatt1,when switch S1 is turned OFF.

Fig.3.4.OperationofZeta–Luoconverter forthreeswitchingstates Mode-IZeta mode

Mode-II [t_1–t_2]: During this interval, switch S1, is turned OFF and diode Do1 starts conducting. ThemagnetizinginductanceLm1releasesthestoredenergyviacapacitorC1tooutputdiodeDo1 andatsecondarywindingofthetransformer.Theoutputdc-linkcapacitorstartschargingthrough the inductance Lo and the battery current is obtained in the CC mode.

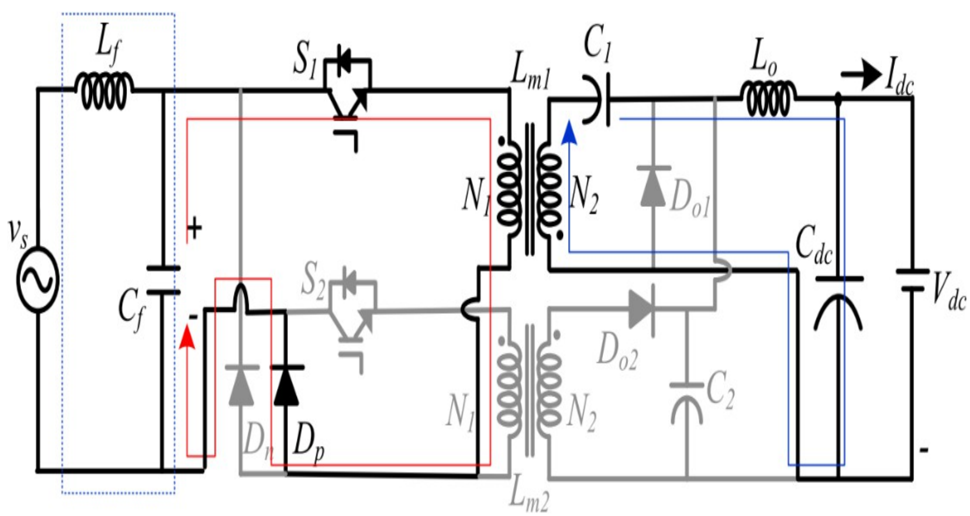

Fig.3.5OperationofZeta–Luoconverterfor three switchingstatesMode-IIZeta mode

Mode-III [t_1–t_3]: During this interval, switch S1 remains OFF and the converter enters the DCM mode.ThesumofcurrentsthroughthemagnetizinginductorLm1andoutputinductanceLoleads to the zero current through the diode Do1, as shown in Figs. 3.3 and Fig.3.4. The capacitor Cdc continues to supply charging current to the battery.

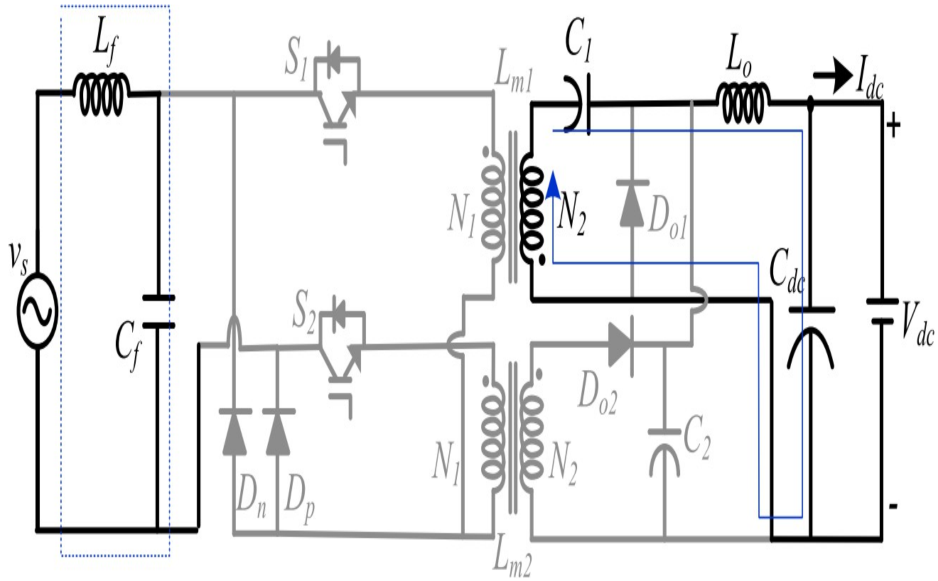

Fig.3.6OperationofZeta–Luoconverterfor three switchingstatesMode-IIIZeta mode

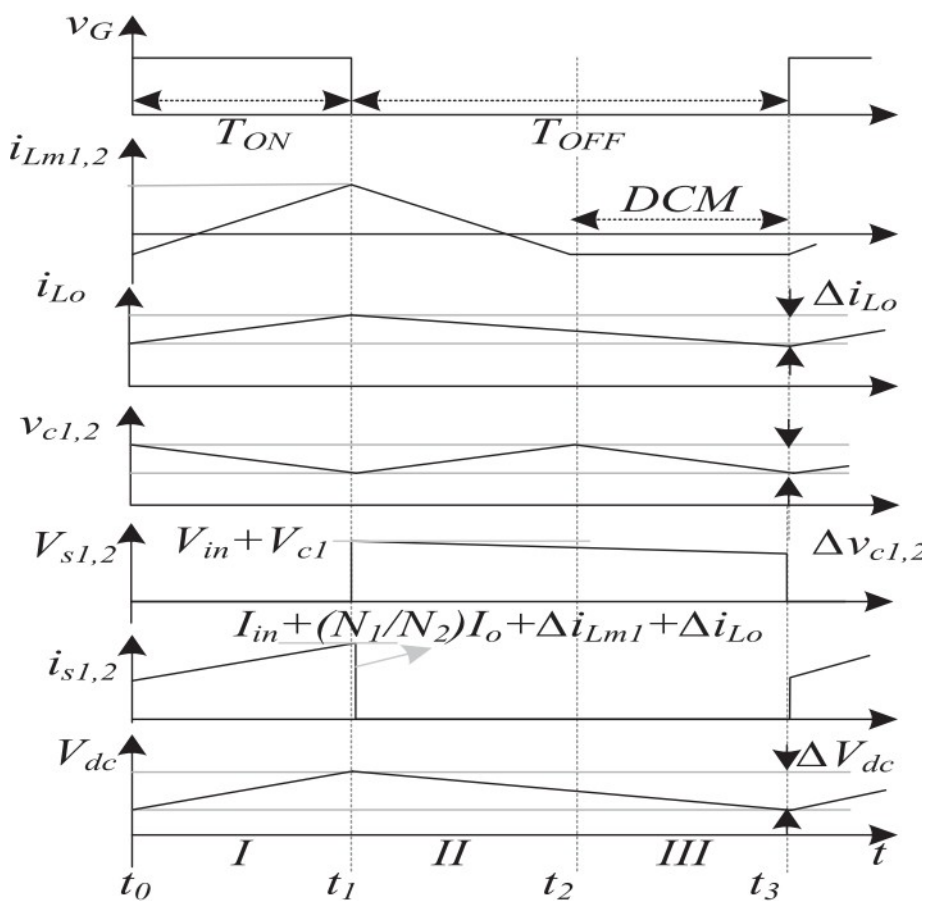

Fig.3.7.Charginganddischargingsequenceofdifferentcomponentsoveraswitchingcyclefor Zeta and Luo modes.

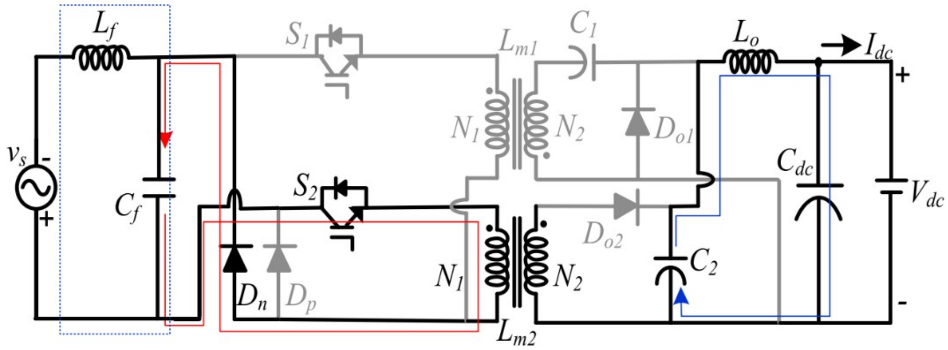

Fig.3.8OperationofZeta–Luoconverterfor three switchingstates Mode-ILuo mode

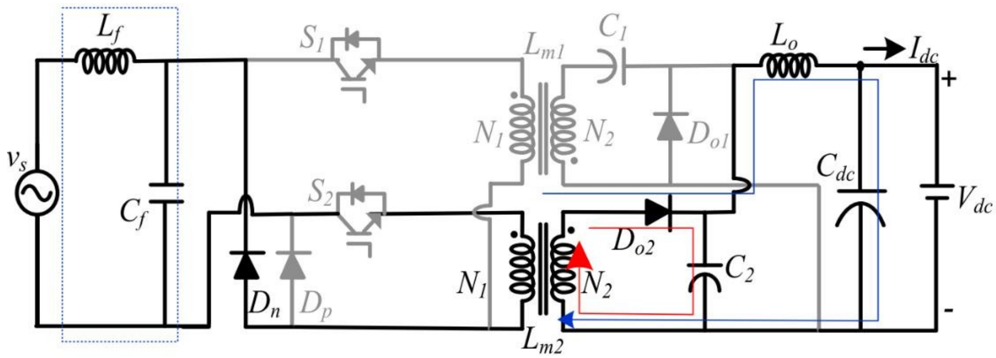

Fig.3.9OperationofZeta–LuoconverterforthreeswitchingstatesMode-IILuomode (–ve half line).

The similar sequences of operations are observed in the Luo mode during the negative half,asshown in Fig. 3.9 .The only difference is that the DCM operation in the Luo converterisidentifiedwiththezerocurrentinthemagnetizinginductance.Fig.3.4showstheassociated waveforms of different switching components over a switching cycle.

C. Summary

The Zeta-Luo converter is a bridgeless isolated dc-dc converter operates in three different modes: Zeta mode during the positive half of the input voltage cycle and Luo mode during the negativehalfoftheinputvoltagecycle. ThethirdmodeistheDCMmode, whichoccurswhenthecurrentthroughthemagnetizinginductororoutputinductorreacheszero.TheZeta-Luoconverter is a promising topology for a wide range of applications, including electric vehicle chargers, battery-powered systems, and renewable energy systems.

IV. SYSTEM DESIGN

A. Introduction

Thedesignof aZeta-Luoconvertersystem typicallyinvolves thefollowing steps:

1) Topology selection: The first step is to select the appropriate Zeta-Luo converter topology for the desired application. There are several different Zeta-Luo converter topologies available, each with its own advantages and disadvantages. The most common topology is the single-stage Zeta-Luoconverter,which is relatively simpleto implement and control. However,there are also dual-stageandmulti-stageZeta-Luoconvertertopologiesthatcanofferimprovedperformancefor specific applications.
2) Component selection: Once the topology has been selected, the next step is to select the appropriate components for the converter. The components must be selected carefully to ensure that they can handle the required power and voltage levels. The most important components to select are the power switches, transformer, and inductors.

B. Battery Control

Thetwo semiconductorswitches oftheBLisolatedconverteroperateindependently but in synchronismduringoneswitchingcycle. BoththepulsestotheconverterdevicesaregeneratedinasimilarpatternusingacascadedPIcontroller.

Thecontrolusesacurrentcontrollertomaintaina CC through the battery up to 80% state of charge (SOC) and a voltage controller, which controls thereducedbatterycurrentuptofullSOC. ForCCcharging,aftersensing thebatterycurrent Idc, it is compared to the reference current $I_{dc_{ref}}$, which is controlled using the voltage PI controller. This comparison leads toan error signal I_{dc_e}, which is obtained at given sampling instant k,using the expression as

$$I_{dc_e}(K)=I_{dc_{ref}}(K)-I_{dc}(K) \tag{1}$$

This error I_{dc_e}, after acomparison, is givento a current PIcontroller, which gives acontrol signal CI at the controller output. At a given instant k, signal CI is expressed as

$$C_1(K)=C_1(K-1)+K_{pI}\{I_{dc_e}(K)-I_{dc_e}(K-1)\}+K_{iI}I_{dc_e}(K) \tag{2}$$

Where $K_{pI}$and $K_{iI}$are the proportional (P) and integral (I) gain constants for tuned current PI controller.TheinputtothevoltagePIcontrolleristheerrorVdce,whichistheresultofcomparison oftwoquantities,i.e.,sensedvoltageVdcandthereferencevoltageVdcref.Thereferencelimitis set at the battery voltage corresponding to 100% SOC. The output of the voltage controller is the signalCv,whichisusedforcurrentreferenceintheCCmode.Theerrorsignalandcontrolvoltage Cv for a given sampling instant k are expressed a

$$V_{dce}(K)=V_{dceref}(K)-V_{dc}(K)$$

$$C_v(K)=C_v(K-1)+K_{pv}\{V_{dc_e}(K)-V_{dc_e}(K-1)\}+K_{iI}V_{dc_e}(K) \tag{3}$$

WhereK_{pv}istheproportionaland K_{iv}istheintegralgainconstantforvoltagecontrol.Therequired gating sequence for two semiconductor devices is obtained after comparing the control signal $C_I$to a high-frequency carrier (m_d). The converter duty cycle is varied over a wide range to ensure an intrinsic PF preregulation over all the operating conditions.

C. Design Of EV Charger

This BL isolated converter is designed in DCM for 780 W (P) rating, and magnetizing inductanceofahigh-frequencytransformer(HFT)isselectedsuchasoperationoftheoutputdiode Do1 or Do2 ceases at the end of each switching period. The supply voltage at the input of this isolated converter, is expressed a

$$v_s(t)=V_{sm}\sin(2\pi ft)=311\sin(2\pi.50t) \tag{4}$$

whereVsandfarermssourcevoltage(peakvalueV_{spk}=$V_s\sqrt{2}$)andfrequency(Hz)oflinevoltage, respectively. The expression to calculate the voltage (V_{dc}) is given as

$$V_{dc}=\frac{N_2}{N_1}\frac{D}{1-D}V_{in} \tag{5}$$

whereDisthedutyratioofthisisolatedconverter inZetaorLuomodesandnistheturnsratioof the transformer. This value is considered as 0.5, which results into the calculated value of the instantaneous duty cycle (D) as

$$D(t)=\frac{V_{dc}}{(\frac{N_2}{N_1})V_{in}(t)+V_{dc}} \tag{6}$$

To achieve a built-in PFpreregulation over the supply voltage variation range of 160–260 V, the dutyratio($D_a$andD_b)isestimatedas0.35and0.26,respectively,forchargingduration.Toobtain theDCMoperation,themagnetizinginductanceLm1,2isselectedforan allowablecurrent ripple of two times the input current. The calculation for the critical magnetizing

$$I_{m1,2c}=\left(\frac{V_{smin}^2}{P}\right)\frac{T_s}{2nv_{in}+V_{dc}}V_{dc} \tag{7}$$

$$=\left(\frac{160^2}{780}\right)\frac{1}{2\times 20000}\frac{V_{dc}0.5\times 1}{60\sqrt{2}+65}$$

$$=0.295\ mH$$

hereT_s(= $1/f_s$) is the switching period for this isolated converter, selected as 50 μs (1/20 kHz). Themagnetizing inductance($L_{m1,2c}$)is selected lowerthan the calculated one, i.e., *0.1 mH*or *100 μH* to prevent the current through the diode at the end of every switching interval. For a voltage ripple(ϒ)of20%inthevoltageacrosstheintermediatecapacitances$C_{1,2}$andtotransfertheenergy efficiently from HFT primary to secondary winding, the value of intermediate capacitor $C_{1,2}$is obtained as

$$C_{1,2} = \frac{v_{in} n^2\{D(t)\}^2}{\Delta V_{w1,2}(t) R_{dw} f_s\{1-D(t)\}} \tag{8}$$

$$= \frac{nP}{\gamma\sqrt{2}V_{smax} f_s (n\sqrt{2}V_{smax}+V_{dc}}$$

$$= \frac{0.5\times 780}{0.2\times 260\sqrt{2}\times 20000\times(0.5\times 260\sqrt{2}+65}$$

The value of intermediate capacitances is obtained as 1.03 μF, which is calculated at rated dc voltageand maximum sourcevoltage (i.e., V_{smax}=260 V). Therefore, to ensurethecontinuity in energy transfer, over a switching interval, a *1 μF* value is selected in this application. To ensure the continuity in the output current and for an allowable ripple current of 20% at the output, the estimation for output inductance L_0, is given as

$$I_o = \left(\frac{V_{smin}^2}{P}\right) \frac{V_{dc}}{k\sqrt{2}V_{smin} f_s} \frac{V_{dc}}{n v_{in}+V_{dc}} \tag{9}$$

$$= \left(\frac{160^2}{780}\right) \frac{65}{0.2\sqrt{2}\times 160\times 20000} \frac{65}{0.5\times 160\sqrt{2}+65}$$

$$= 0.795\ mH$$

Therefore,avalueof $L_o$ischosenas*0.8mH*here.Toavoidthesecondharmonicrippleincharging current, the estimation of capacitor C_{1dc} , for an allowable ripple voltage of 3%, is achieved as

$$C_{dc} = \frac{I_{dc}}{2\omega\Delta V_{dc}} = \frac{(P/V_{dc})}{2\omega\Delta V_{dc}} = \frac{P}{2\omega\Delta V_{dc}^2} \tag{10}$$

$$= \frac{780}{2\times 314\times 0.03\times 65^2}$$

where ω is the supply frequency (rad/s) and Δ depicts the ripple in converter dc-link voltage. Therefore, a 10 mF value is selected for dc-link capacitance. To avoid the travelling of switching harmonics toward the ac source, an LC-based low-pass filter is designed using the following expressions:

$$C_f \leq C_{fmax} \quad , C_{fmax} = \frac{\left(\frac{P\sqrt{2}}{V_s}\right)}{(\omega\sqrt{2}V_s)} \tan(\cos^{-1} DPF) \tag{11}$$

$$= \frac{(780\sqrt{2}/220)}{(314\times 311)} \tan 1^0 = 896nF$$

whereθisexpressedastheanglebywhichthelinecurrentleadsorlagsthelinevoltage,assumed to be 1°, DPF is the displacement power factor. The estimated value of $C_{fmax}$is achieved as 580 *nF* for this work. Now considering the filter cut frequency as f_{cr}< f_s/10,the inductance L, is calculated as

$$L_f = \frac{1}{4\times\pi^2\times f_{cr}^{\ 2}\times C_f}$$

$$= \frac{1}{4\times\pi^2\times5000^2\times580\times10^{-9}}$$

$$=1.7\ \text{mH}$$

D. Summary

The design of a bridgeless isolated Zeta–Luo converter-based EV charger with PF pre-regulation.Theauthorscomparethistopologytootherexisting EVchargertopologiesanddiscussits advantages,suchasreducedcomponentcount,improvedefficiency,and simplercontrol.Theauthors also discuss the design considerations for the proposed converter, such as the selection of the magnetizing inductance to ensure that the converter operates in discontinuous conduction mode.

V. SIMULATION RESULTS

A. Introduction

Performance of a BL isolated converter-based charger for high power quality is verified. Simulation results are recorded for CC–CV charging, and the explanation for the performance at the steady state and for change in load current and line voltage is given as follows.

B. Validation & Results

PerformanceofaBLisolatedconverter-basedchargerforhighpowerqualityisverifiedon a laboratory prototype with a 48 V 100 Ah battery-based interface is used for control and power circuits of this charger. The picture of developed setup is shown in Fig. 5.1. Test results are recordedforCC–CVcharging,andtheexplanationfortheperformanceatthesteadystateandfor change in load current and line voltage is given as follows.

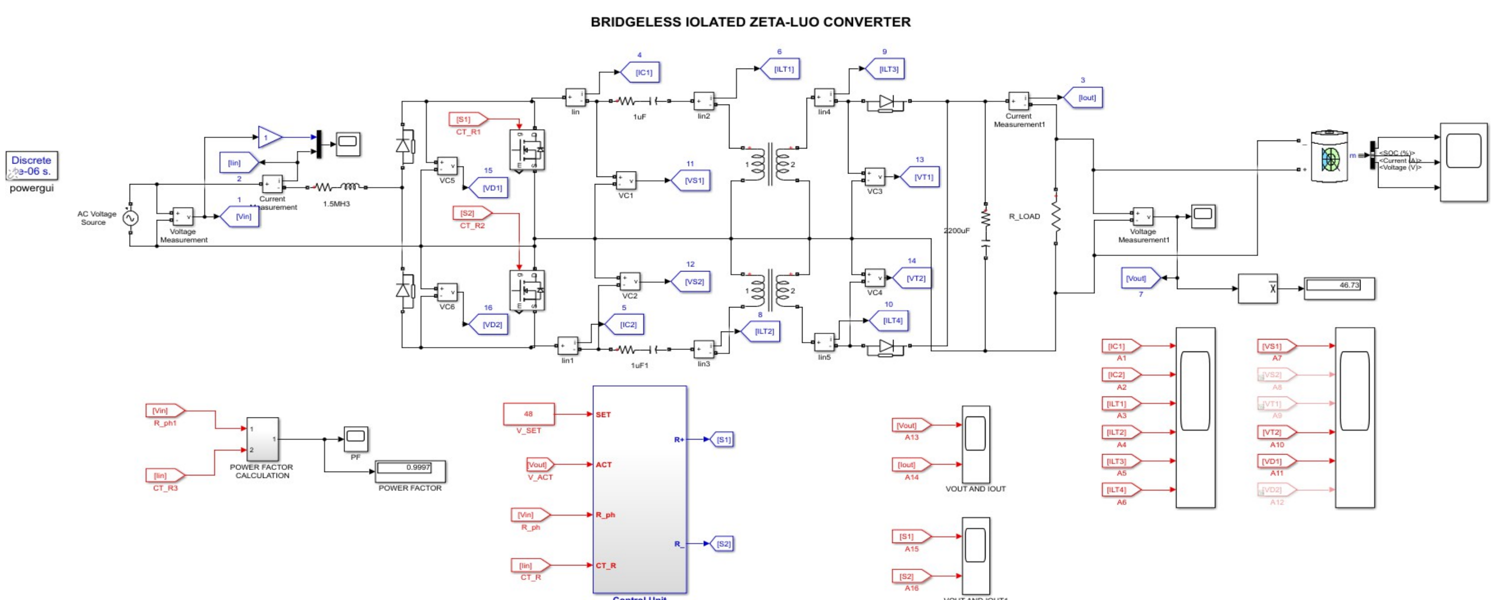

Fig.,5.1,CircuitDiagram forZeta-LuoConverter

1) PFPreregulationofCharger

The steady-state high PQ operation of this charger is shown as per Fig. 5.1, which records the waveforms of the battery voltage Vdc and the battery current Idc with the line voltage vs and line current is. It is clear from the battery current waveform that for this new charger, the integration of the Zeta and Luo converter reduces the ripple in charging current as the output inductorissharedinbothmodes.Therefore,asmoothchargingcurrentisavailableforthebattery.
Therippleinbatterycurrentisseentheseripplesaffectthebatteryhealthinlong-termapplications.

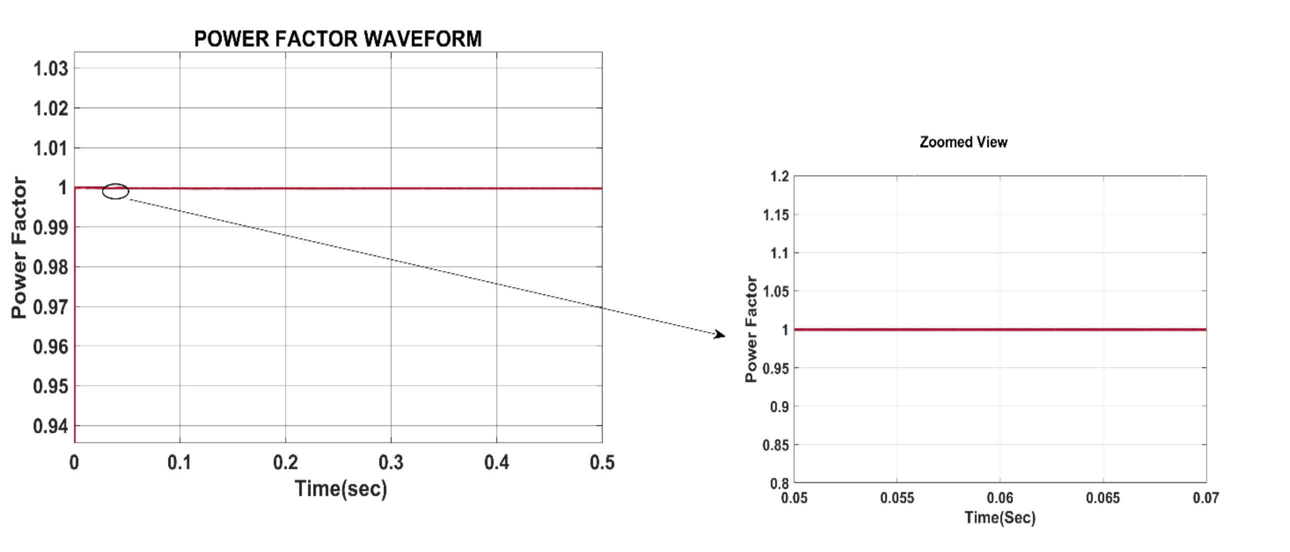

Fig.5.2,PowerFactorWaveform

2) ConverterPerformance

at Steady State The performance of the charger with the BL isolated converter is validated at the steady state, as per Fig. 5.2. This converter works in BL configuration with Zeta operation in positive half line and with Luo operation in negative half line. As shown in Fig. 5.3 the performance of primary side energy transfer capacitors is found satisfactory with the continuous voltage seen across them over a switching cycle. The capacitors C_1, C_2work in Zeta and Luo modes during the positive and negative half cycles, respectively. Similarly, the waveforms of the outputinductorscurrentsin CCMarerecordedfortwomodes, showsthemeasuredvoltageacross and current through the PFP switches S_1,S_2, which clearly demonstrates an acceptable range of peakvoltagestressat510 Vandacurrentstresslimitof 35Afor780Wdesign.Itisobviousthat theincorporationofthe Luoconverterinthenegativehalfcycleavoidstheuseofanextrainductor due to sharing of output stage of charger. Moreover, the use of output inductance at both halves also minimizes the pulsation in output current, then that in case the Zeta converter used for both cycles. It is implied from Figure that this charger operates in DCM. The selected value of magnetizinginductances oftheHFtransformer$L_{m1,2}$areinanappropriaterangetoensure discontinuouscurrentthrough boththe windings, during a switchingcycle, aswellasover the respective half cycle.

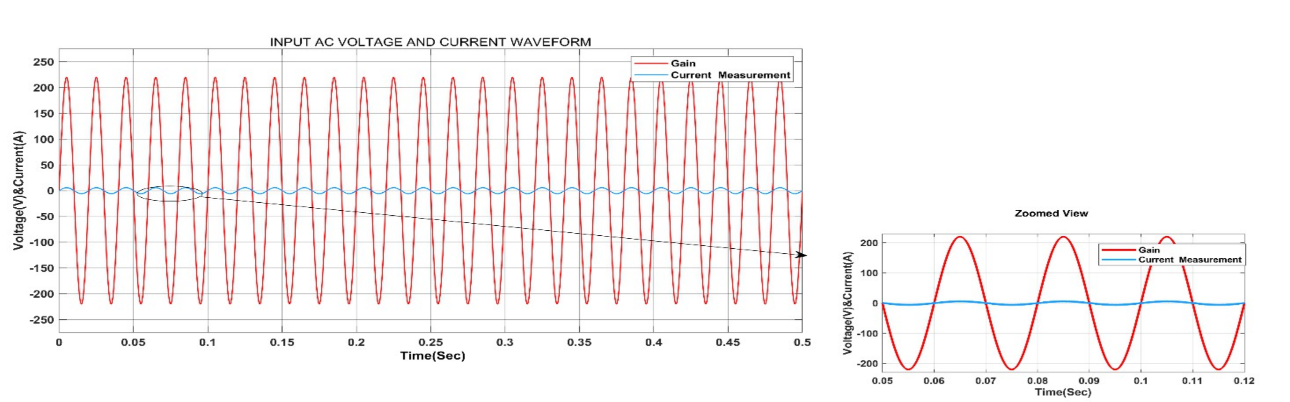

Fig.5.3,InputACVoltageandCurrentwaveform

3) UPFOperationatDifferentLineVoltages

The operation of this BL isolated converter for high PQ performance is investigated under sudden fluctuations in input voltage. It is to be mentioned that as per Fig.5.2, an improved PF- based charging is validated and the line current THD is lowered to the permissible harmonic's standard during the two-line voltages.

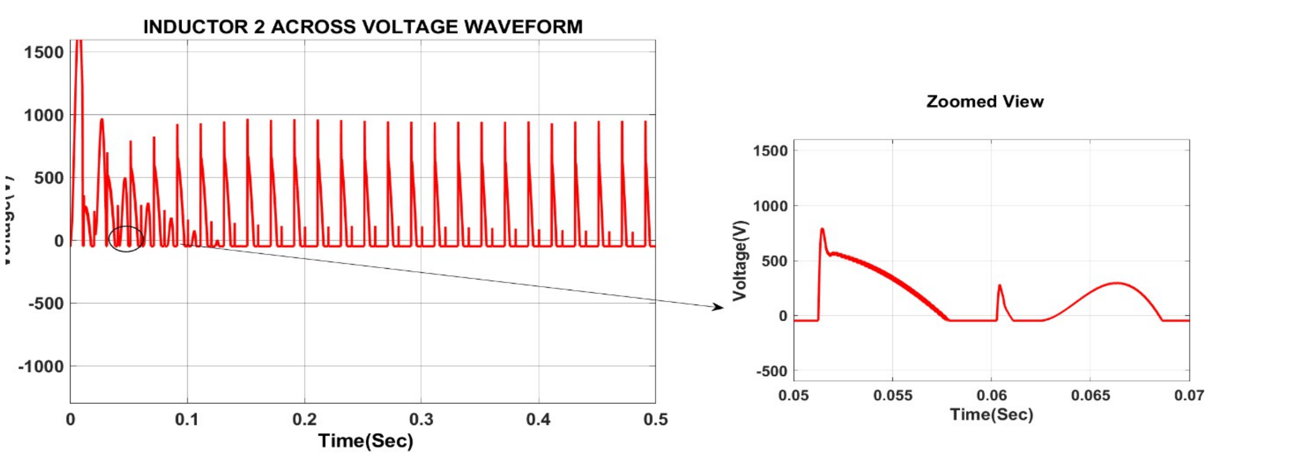

Fig.,5.4, InductorVoltage Waveform

ACV,Vdcisobservedacrossthebatteryforthecompleterangeoffluctuation.ThebatterychargingduringCCchargingisobservedwithconstantlowripple,liketheratedlinecondition.

However, to sustain this change in ac voltage from 220 V, an increased and decreased in line current,respectively,foradipandahikeinlinevoltage,arerecorded,whichvalidatestheconstant charger output. The improvement in input side indices, such as displacement PF, line PF, crest factor, and THD in line current, are observed as per Figs5.4 . The recorded power profile for the power transfer is shown with apparent power, active power, and reactive power

4) PerformanceatVariationinLoadcurrent

The performance of this charger is validated for step change in load current, i.e., the battery current i_{dc}ischangedfrom50%.Therecordedwaveformsofthegridvoltage,thegridcurrent,thebatteryvoltage,andthebatterycurrentareshowninFig. 5.6andFig.5.7,Tovalidatetheconverter performanceduringincreaseintheload,achangeinthebatterycurrentisintroducedfrom5to10 A.

A corresponding rise in the grid current is observed as per Figure as the load demand is increased. Similarly, for step reduction in the load demand, the battery current is lowered from rated to 5 A. As a result, a dip in the grid current is recorded. Therefore, despite a step change in the load current, the closed-loop performance of the converter is found satisfactory as shown in Fig.5.5.

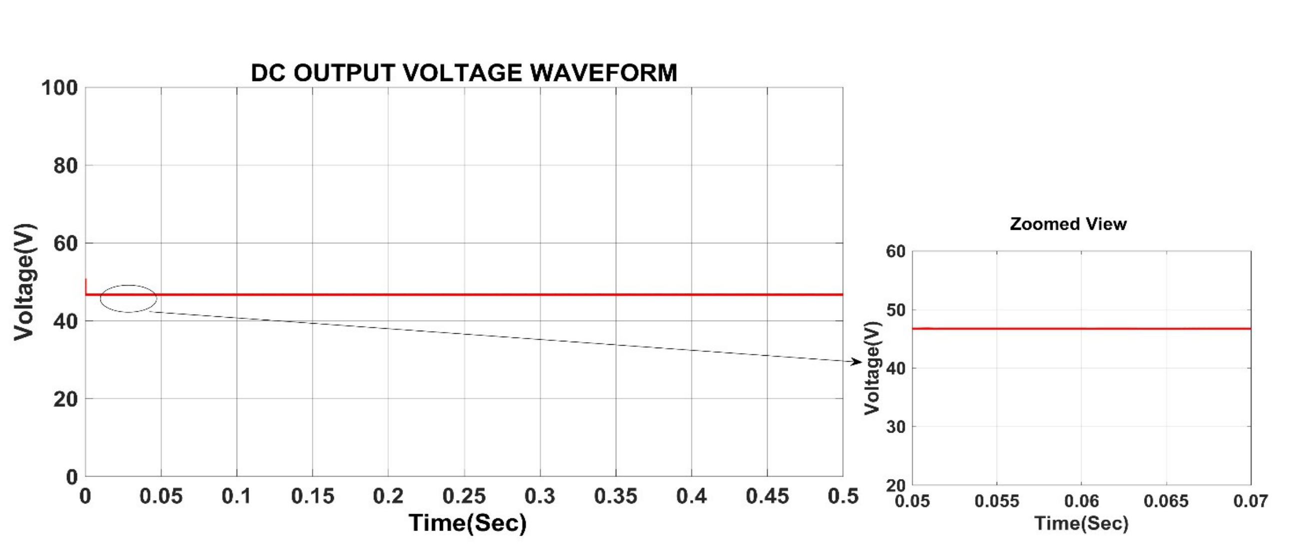

Figure5.5, DCOutput VoltageWaveform

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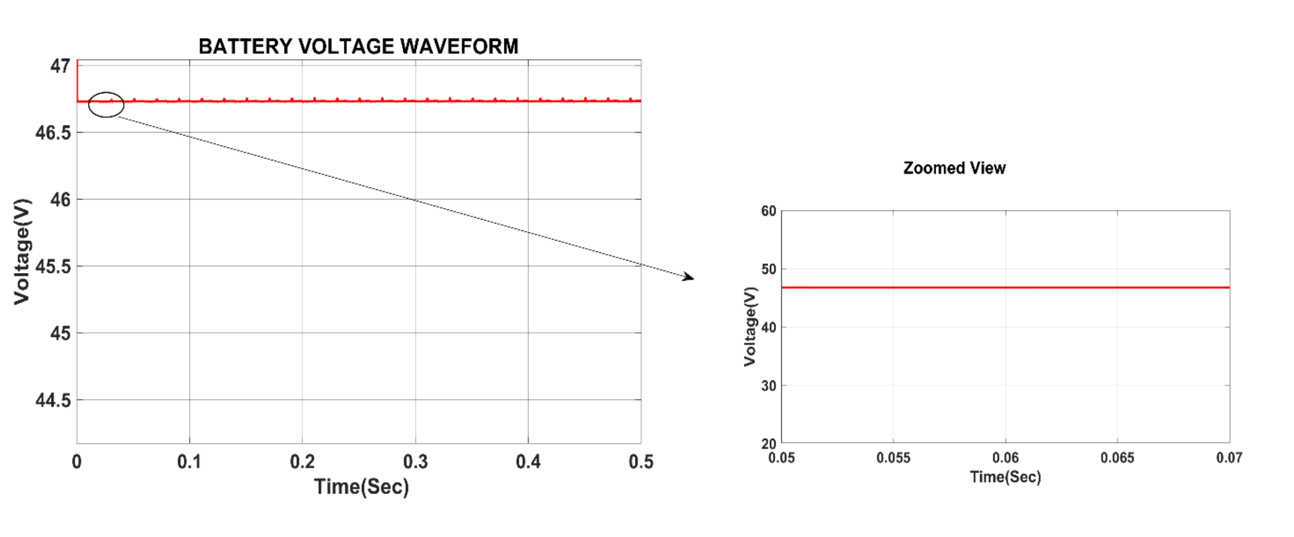

Figure5.6,Battery VoltageWaveform

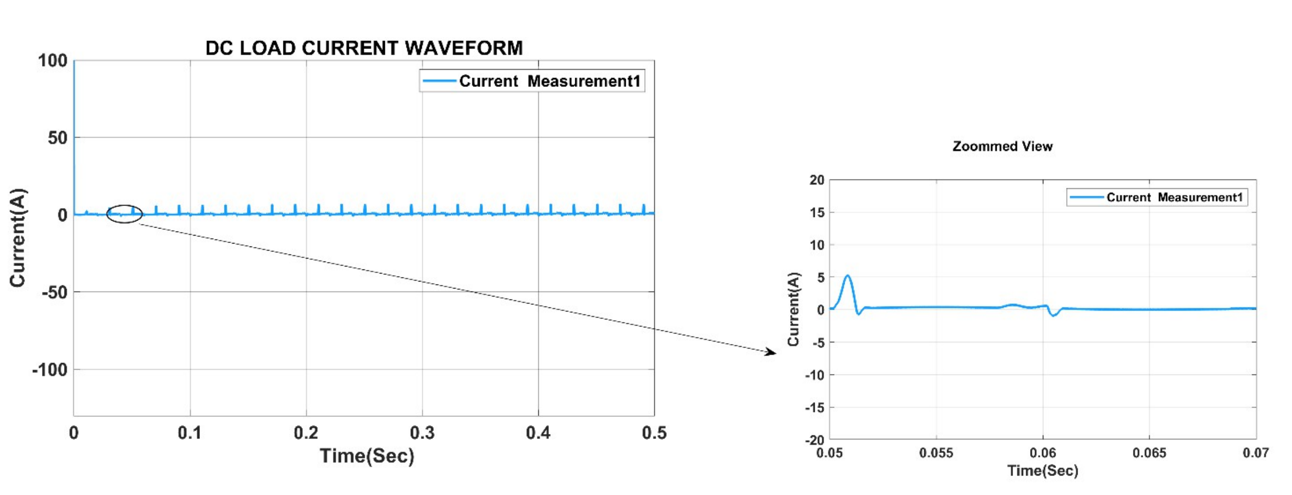

Figure5.7,DCLoadCurrentWaveformsWaveform

C. Summary

TheproposedbridgelessisolatedZetaLuoconverterbasedEVchargerisanewtypeofEVchargerthatIthasahigherefficiencythanpreviouslydevelopedEVchargers,onaccountofsharing theoutputinductorsforbothconverters.Itprovidesauniformchargingcurrentforthebattery,due to the presence of output inductance in both converters. Achieves unity power factor (UPF) at steady state and for a variation in mains voltage and loads. The power quality (PQ) indices at the supply side conform to the recommended IEC 61000-3-2 guidelines for all the operating conditions. The experimental verification shows that the proposed EV charger is a promising candidate for future EV charging applications.

VI. CONCLUSION AND NEXT PLANNING

A. Conclusion

Theworkcarriedoutinthereportcanbesummarizedbrieflyasfollows.AnimprovedPQbasedBLisolatedZetaLuoconverterhadbeendesigned inDCMforthe EV battery charger. This configuration was achieved with combined Zeta and Luo converters, whichweredesignedtoworkduringindividualhalvesofsupplyvoltage.Thisgivesanadditionalbenefitofhigherefficiencythanthepreviously developedconvertersonaccountofsharingoutput inductors for both converters.

Therefore, the charger cost and size were reduced. Moreover, a uniform charging current was obtained for the battery due to the presence of an output inductance in both converters, as compared to the Zeta or Luo converter was used for both cycles. Similar pulses were applied to both devices during UPF operation; therefore, the gate drive and control implementation were easy.

TheperformanceofthischargerwasrecordedasperanIEC61000-3-2standardguidelines, over the entire operating range of line and loadings. The line current was reshaped to sinusoidal and unity PF was achieved for a complete range of mains voltage. The source current distortion wasmeasuredaslowas4.1%,3.4%,and4.3%duringCCchargingand7.1%duringtheCVmode. Therefore, this PF preregulation-based BL isolated converter seemed to be an improved solution for commercially cost effective off-board charging.

The BL topology and shared output inductors significantly reduce semiconductor losses, leadingtoimprovedefficiency.Thebuilt-inPFPreregulationcapabilityensuresnear-unitypower factor operation, minimizing reactive power consumption and improving grid stability. The elimination of bridge rectifiers and the sharing of output inductors result in a compact and lightweightchargerdesign.Enhancedperformanceundersuddenvoltagevariations:Theproposed charger exhibits robust performance under sudden line voltage fluctuations, ensuring reliable EV charging even during unstable grid conditions.

The Bridgeless Isolated Zeta–Luo Converter-Based EV Charger With PF Preregulation presents a promising solution for efficient and reliable EV charging. Its combination of high efficiency, improved power factor, reduced size, and enhanced performance under voltage variations makes it an attractive choice for future EV charging infrastructure.

B. *Next Planning*

Theplanning forthe remainingwork isgiven below.

Sr. No.	Detailsofwork completion	Dates	Expectedoutcomes
1	ClosedLoop Simulation	Dec-2023	Closed Loop MATLAB SimulationforZeta–Luo Converter
2	Hardware	Jan-2024	Purchaseof Instrumentsfor modelwithproper parameters
3	Implementationon hardware	Feb-2024	Connectingtheinstruments andformHardware model
4	Report	Feb-2024	FinalProject Report

Table.6.1NextPlanningof project

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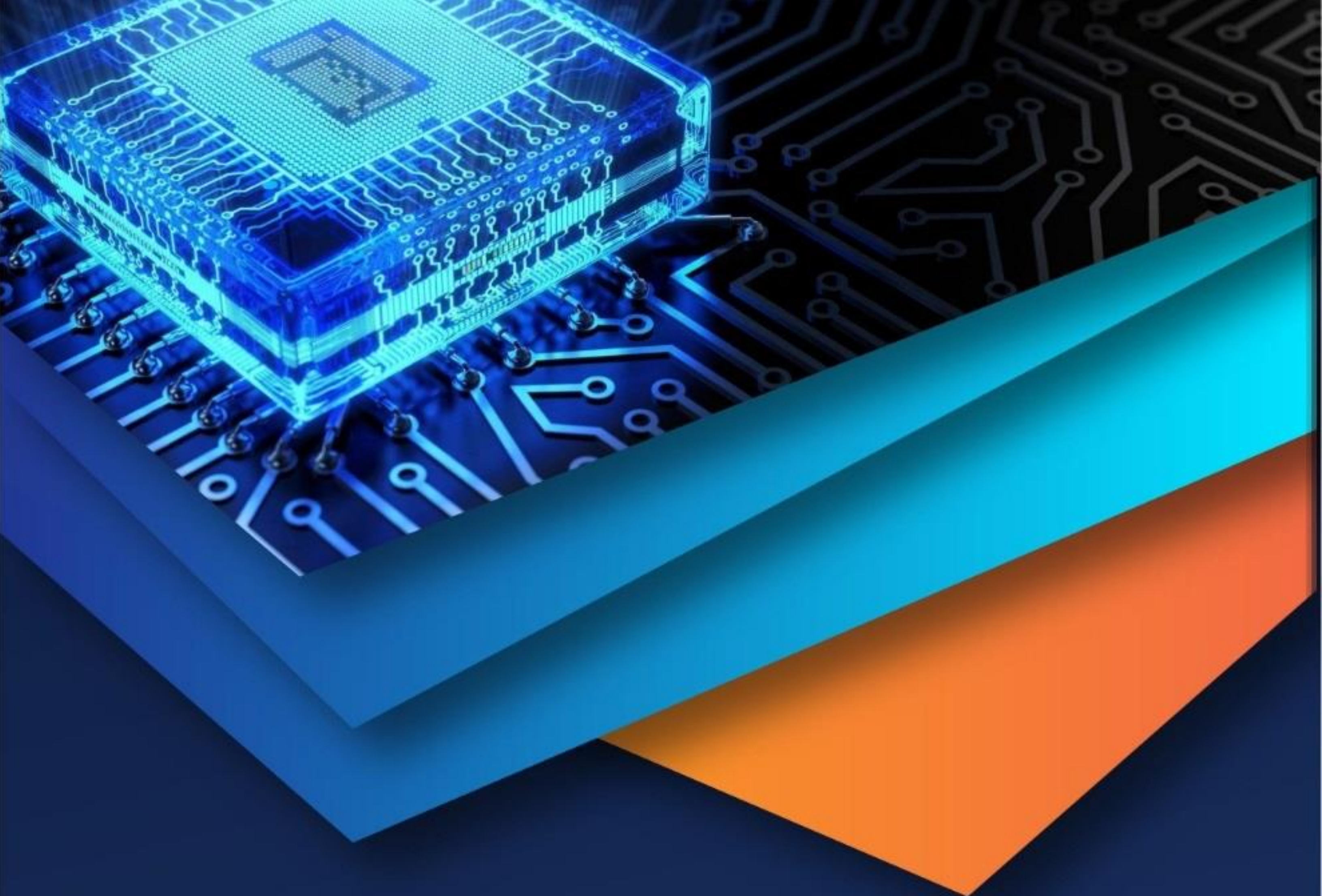

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