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MODIFIED Z-SOURCE UNIFIED EVDC CHARGER DESIGN

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Abstract:- Sun based Energy has been the most well known wellsprings of sustainable power source for private and semi business applications. Changes of sun oriented vitality gathered because of air conditions can be relieved through vitality stockpiling frameworks. Sunlight based vitality can likewise be utilized tocharge electric vehicle batteries to diminish the reliance on the lattice. One of the prerequisites fora converter for such applications istohave a diminished no. of change arranges & give confinement. Z-source inverter (ZSI) topology can evacuate different stages and accomplish voltage lift and DC-AC control transformation in a solitarystage. The utilization aloof parts additionally displays a chance to incorporate vitality stockpiling frameworks (ESS) into them. This article presents displaying, plan and activity of a changed Z-source inverter (MZSI) incorporated witha split essential disconnected battery charger for DC charging of electric vehicles (EV) batteries. Reproduction and test results havebeen introduced forthe evidence of idea ofthe activity of the proposed converter.

Index Terms:-Z-source-inverters;Active filter; EnergyStorage; photovoltaic (PV) power generation; quasi-Zsource inverter (qZSI); Single-PhaseSystems; transportation electrification; Solar energy; distributed power generation,inverter.

I. INTRODUCTION

CHARGING of electric vehicles atpresent intensely includes utilization AC framework. The different strategies for charging only use AC lattice, for example, remote charging or module charging can at present reason contamination independent of how profoundly proficient the topology is. The measure of petroleum derivatives that are expended to produce the vitality to charge an electric vehicle gives a more clear image ofthe carbon impression thatis deserted while charging an electric vehicle. To accomplish lower carbon impressions, one of the ways is to incorporated sustainable power sources intoa charging framework to diminish the reliance onthe AC lattice. A noteworthy necessity for planning an EVbattery charger isthe utilization of disconnection transformers in theconverter topologies, give galvanic seclusion at the client endfrom the remainder of the high voltage (HV) framework as a security measure [1]. The galvanic seclusion can be given either on the AC matrix side or on the charger side. The sizeof the confinement transformer on the lattice sideis typically a lot bigger than the one on the charger side [2]. Because of the improvement in semiconductor innovation, high recurrence exchanging encourages the utilization of littler size transformers forgalvanic disconnection. Photovoltaic matrix interconnected frameworks havebeen utilized in the past for business charging foundation [3]. These frameworks decrease the reliance ofthe charging foundation on the AC network. The utilization of sunlight based and lattice interconnected framework is an appealing answer for private charging frameworks for EVs. For frameworks upto 10 kW, single stage inverters canbe utilized for private applications [4][5]. For interconnection ofthe private sun based PV to the lattice, different disconnected and non segregated topologies are accessible with various stages [4][6]. Private photovoltaic frameworks for EV charging require highlights, for example, seclusion and voltage support capabilty to coordinate the sun powered PV cluster voltage to the lattice voltage prerequisites. The ZSI topology was first presented in [7]. It has a capacity to buck or support and alter the information DC voltage in a solitary stage. It has increased enormous enthusiasm for photovoltaic-network associated applications. The ZSI topology utilizes two capacitors and two inductors to support the information DC voltage to coordinate the inverter side AC yield voltage prerequisites. The activity of a ZSI is vigorously reliant on the uninvolved parts. It introduces a chance to incorporate vitality stockpiling units into such a framework. In this paper a proof of idea of a solitary stage MZSI based sun oriented matrix associated charger has been displayed as an application towards a string inverter setup. In area II, the fundamental activity standard for a ZSI have been talked about alongside the part plan. Segment III, examines the measuring of parts, demonstrating and control of the converter. Segment IV, displays the reproduction results for the activity of a 3.3 kW proposed inverter charger and results from a test arrangement worked as a proof of idea. Segment V, displays the end.

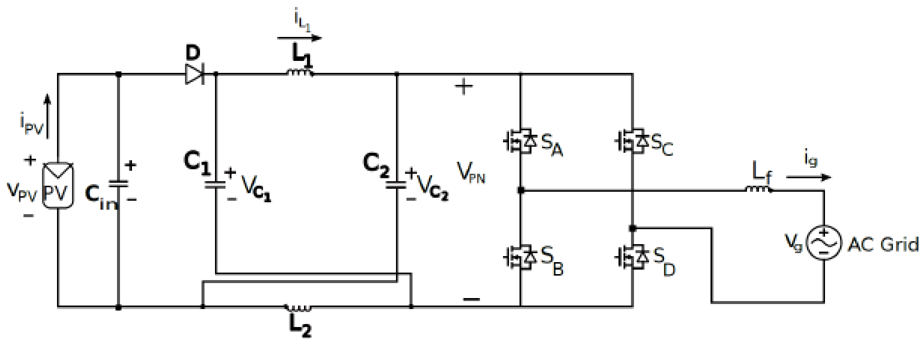

Fig. 1. Schematic of a Photovoltaic/AC grid inter- connected Z-source Inverter(ZSI)

II. TRADITIONAL ZSI

The ZSI topology, appeared inFig.1, uses two methodsof activity: theshoot through state and the non-shoot throughstate[7]. Forsymmetrical tasks,

$$i_L = i_{L1} = i_{L2} \quad (1)$$

$$V_C = V_{C1} = V_{C2} \quad (2)$$

From Fig.1, in the shoot through express, every one ofthefour switches, S1, S3, S2 and S4, are leading simultaneously. The term ofthis shoot through stateis depicted by the obligation cycle D0 andthe exchanging recurrence FSW.

The shoot through state can be executed by a changed PWM method exhibited in [7]. Accordingly, the two capacitor voltages are communicated as [7]:

$$V_C = \frac{1 - D_0}{1 - 2D_0} v_{pv} \quad (3)$$

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Subsequently, keeping up a higher pinnacle voltage at the contribution of the DC interface, V_{PN}. The pinnacle DC connect voltage, $\hat{V_{PN}}$, is given by[7]:

$$\hat{V_{PN}} = \frac{1}{1-2D_0} v_{pv} \tag{4}$$

The powerbalance condition betweenthe DC and AC side ofthe ZSI is communicated as [7],

$$(1-D_0)\hat{V_{PN}} I_{PN} = i_{grms} v_{grms} \tag{5}$$

Where I_{PN} and $\hat{V_{PN}}$ are the pinnacle DC interface currentandvoltage. The pinnacle AC voltage ofthe ZSI is [7]:

$$V_g = M\hat{V_{PN}} \tag{6}$$

where the M is the modulation index, grid voltage, $v_g = V_g \sin\omega t$ and the grid current $i_g = I_g \sin(\omega t + \varphi)$. For $\varphi=0$ for grid connected applications. From equation (11) and (13) the RMS of the output AC voltage of the ZSI is [7]:

$$V_{grms} = \frac{M v_{pv}}{\sqrt{2}(1-2D_0)} \tag{7}$$

III. COMPONENT SIZING, MODELING AND CONTROL OF PROPOSED MZSI

Fig. 2 demonstrates a changed Z source inverter has been proposed having an incorporated charger. The MOSFET SR permits bidirectional activity of the MZSI when required. The diode DPV obstructs the turn around stream of current once again into the PV. Rin is the interior opposition of the info capacitor C_{in}. For symmetrical activity of the MZSI, a split essential segregated DC to DC converter has been proposed for the joining of the charger side into the ZSI. The split primaries contain two half extension converter (HBC) primaries confined from a solitary full scaffold optional through a high recurrence transformer. The HBC primaries and the secondaries are worked at half obligation cycle in open circle. The yield current of the auxiliary is associated with a vitality stockpiling unit, for example, a lithium-particle (Li-particle) battery. The vitality stockpiling unit cinches its own voltage, vB, over the contribution of the HBC primaries, VC, with the end goal that,

$$V_C = 2v_B \tag{8}$$

A. Maximum Shoot Through Duty Ratio, D_{0max}

Because of the vitality stockpiling unit being associated over the capacitors, the most extreme shoot through obligation proportion, D0max is determined dependent on the base information voltage, v_{pvmin} and the greatest battery voltage, V_{Bmax} associated over the capacitors and is communicated as:

$$D_{0max} = \frac{2V_{Bmax} - v_{pvmin}}{4V_{Bmax} - v_{pvmin}} \tag{9}$$

SAE J1772 standard defines the standard battery voltages for DC charging between 200V-500V.

B. Inductor L_1 and L_2 design

The inductors L_1 and L_2 are estimated for high recurrence top to top current swell expected between 15-25% of theFig. 2. Point by point Schematic of Proposed MZSIinductor current duringthe shootthroughtime interim $\frac{D_0 T}{2}$as follow [8]:

$$L_1 = L_2 = \frac{V_{Cmax} D_{0max}}{2\Delta i_L f} \tag{10}$$

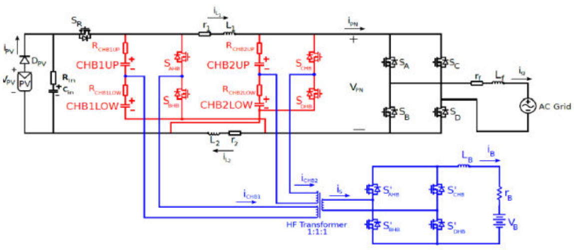

Fig. 2. Detailed Schematic of Proposed MZSI

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C. Capacitor C_1 and C_2 design

The capacitorsare measured to retain the second request symphonious part in the capacitor voltages as pursue [8]:

$$L_1 = L_2 = \frac{V_{Cmax} D_{0max}}{2\Delta i_L f} \quad ($$

where V_C is the normal voltage over the capacitors V_{C1} and V_{C2} and ΔV_C is the foreordained voltage swell point of confinement. ω isthesecond request sounds communicated inrad/s. In single stage Z source inverters, curiously large electrolytic capacitors for second request music concealment can bring about a cumbersome framework. A DCside Active Power Filter(APF) proposedin [9], can be utilized to lessen the capacitance required. It works autonomous of the activity ofthe MZSI. For theproposed topology, most extreme capacitor voltageratingis equivalent to atleast double the pinnacle voltageofthe vitality stockpiling gadget clasped crosswise over it.

D. Average Modeling of the Integrated Half-Bridge DCDC Converter Charger

At the point a vitality stockpiling unit is associated with the auxiliary side of the charger then every one ofthe split primaries works on the other hand and supplies a large portion of battery. Every one of the primaries ofthe DC-DC converter is associated over the capacitors ofeither legs. The voltage over the capacitors is characterized by the condition (15). The definite normal displaying of the split essential DC-DC converter is clarified in [10]. Every one ofthetwo primaries can be spoken to utilizing a RLEcircuit associated parallelto every one of the capacitor, C1 and C2, as appeared inthe simplfied proportional modelof the Fig.4.

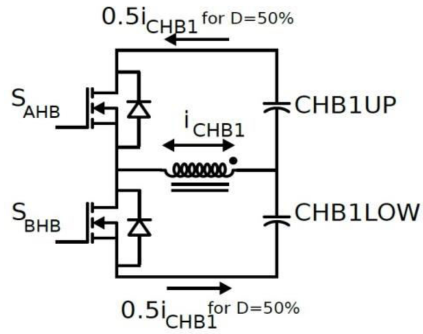

Fig. 3. Schemetic of one the Primary across CHB1 operating at 50% duty cycle.

E. State Space Average Modeling of the Single Stage Inverter Charger

The nitty gritty state space normal displaying was introduced in [10]. The equal graph of the demonstrated MZSI is ahown in the Fig. 4, During the non shoot-through express, the KVL condition is given by:

$$L\frac{di_L}{dt} = v_{pv} - i_L r + R_{HB} + (2\hat{i_g} + \frac{i_B}{2})R_{HB} - V_C$$

The KCL equation is:

$$C\frac{dV_C}{dt} = i_L - \hat{i_g} - \frac{i_B}{4} \qquad (13)$$

During the shoot-through express, the KVL condition is:

$$L\frac{di_L}{dt} = V_C - i_L(R_{HB} + r) - \frac{i_B}{2}R_{HB} \qquad (14)$$

The KCL equation is written as:

$$C\frac{dV_C}{dt} = -i_L - \frac{i_B}{4} \qquad (15)$$

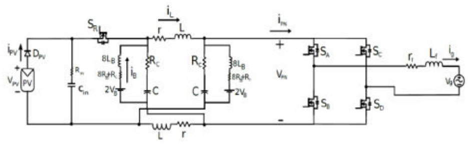

Fig. 4. Equivalent Model of the proposed Modified Z-source Inverter(MZSI) with battery

From condition (12)- (15), state space conditions for the whole framework can be composed as:

$$\begin{bmatrix} \dot{i_L} \\ \dot{V_C} \\ \dot{i_B} \end{bmatrix} = \begin{bmatrix} -\frac{-(r+2R_{HB})}{L} & -\frac{1-2D_0}{L} & \frac{(1-2D_0)}{2}R_{HB} \\ \frac{1-2D_0}{C} & 0 & -\frac{1}{4C} \\ \frac{1-2D_0}{L_B}R_{HB} & \frac{1}{2L_B} & -\frac{R_{HB}+R_B}{2L_B} \end{bmatrix} \begin{bmatrix} i_L \\ V_C \\ i_B \end{bmatrix} + \begin{bmatrix} \frac{2(1-D_0)R_{HB}}{L} \\ -\frac{1-D_0}{C} \\ -\frac{(1-D_0)R_{HB}}{L_B} \end{bmatrix} [i_d] + \begin{bmatrix} \frac{(1-D_0)}{L} \\ 0 \\ 0 \end{bmatrix} [v_{pv}] + \begin{bmatrix} 0 \\ 0 \\ -\frac{1}{L_B} \end{bmatrix} [V_B] \quad (16)$$

Fig. 4 demonstrates thepositive bearings of thebattery current, i_B, andthe network side AC current, ig.

Fig. 5 demonstrates the square outline for topology. It comprises of three circles: the PV current ipv_{loop}, matrix current ig_{loop} and the battery current iBloop.

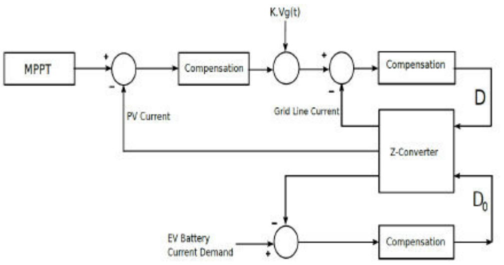

Fig. 5. Square graph of the Control Scheme Proposed Modified Zsource Inverter Charger In writing, the ZSI capacitor voltageis controlledto produce the referencecurrent for the H-connect inverter yield current [11] or create the shootthrough obligation proportion D0 [12]. In this article the referencecurrent is produced by controlling the pinnacle input photovoltaic current [13]. On the off chance that a solid voltage VC is associated crosswise over either or the two capacitors, the shoot through obligation proportion, D0, will rely upon VC. Since the battery current circle don't require quick powerful changesbattery circle controlisthe slowest reaction contrasted with the information currentcontrol. For thebattery circle control the exchange capacity isgiven by:

$$\frac{I_B(s)}{d_0(s)} = \frac{-sC[4R_{HB}i_L - 2R_{HB}i_d] - [2i_L - i_d]}{2L_BCs^2 + sC[R_{HB} + 2R_B] + 0.25} \quad (17)$$

A feed forward is added to the battery control loop,

$$FF_B = \frac{2V_B - v_{PV}}{4V_B - v_{PV}} \quad (18)$$

where VB is the yield voltage of the HBC and vPVis the followed PV voltage.

The yield AC side current controller ought to have the quickest reaction.

F. Energy Management Scheme for the Proposed Converter

Fig. 6 demonstrates a rearranged square outline oftheproposed framework. At the point when an ESS is incorporated into a ZSI, the condition (5) is changed as pursues [14]:

$$v_{PV} i_{PV} = v_b i_b + i_{grms} v_{grms} \quad (19)$$

where i_{band} v_{bare} the battery and voltage. Fig. 6 demonstrates thatthe single stage AC lattice control $P_{gbalances}$ the power variance of the photovoltaic source P_{pvthus} a steady charge control, PB, is acquired attheESS. For EVbattery charging utilizing both the single stage AC lattice & photovoltaic power, the heading of the AC framework current $i_{gchanges}$ to negativewhile drawing power fromthe matrix.

The inverter side canbe worked bidirectionally and thePV & framework gives capacity to the charger, keeping up the power balance.

$$v_{PV} i_{PV} + i_{grms} v_{grms} = v_b i_b \quad (20)$$

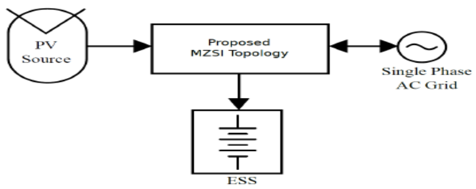

Fig. 6. Simplified BlockDiagram ofthe System

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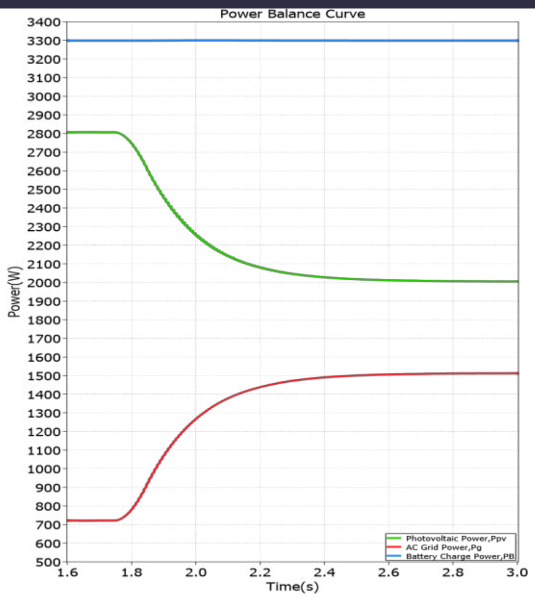

Fig. 7. Simulation Waveform forthe power balancebetween the Photovoltaic input power, the ACGrid side and thebattery power.

For whatever length of time that the voltage over the info capacitor Cinis kept up to atleast the base estimation of the PV voltage, the MZSI can be worked as a lattice associated rectifier/charger without the PV [15]-[16]. Against islanding security methods for the ZSI topology have been tended to in writing already in [17].

IV. SIMULATION AND EXPERIMENTAL RESULTS

A. Simulation study for a MZSI operation

The reproduction concentrates to show the conduct ofthe proposed topology havebeen completed utilizing PLECS 4 for a 3.3 kW charger for a string inverter design. Recreation has been completed for the framework appeared inFig.2. Fig.7 appears at reenactment timet=1.75 s, the information PV power lessens from2.8 kW to 2 kW, the matrix power increments from 710 W to 1500Wto keep up the yield charger capacity to 3.3kW and the relating lattice current, DC interface voltage, appeared in Fig.8.

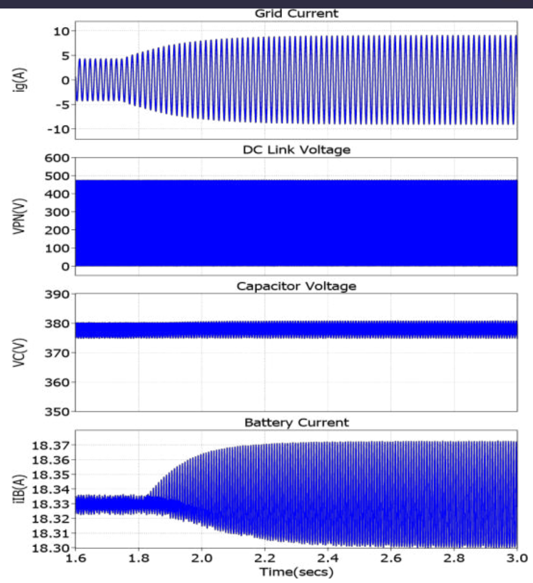

Fig. 8. Reproduction Waveform ofthe lattice current,Ig, DC connect voltage,VPN, Capacitor Voltage,VC1, andBattery current,ibfor the powerbalance betweenthe Photovoltaic info control, the AC Grid side andthebattery control.

Table I: Modified Z_{si} BasedCharger System SimulationSpecifications

Parameters	Value
Input Voltage, V_{in}	286 V
Input Current, I_{in}	9.8 A
Inductor Value, L_1=L_2	500 uH
ZSI Switching Frequency, F_{SW}	25 kHz
Grid Voltage (RMS), V_g	240 V
Inverter Output Filter Inductor, L_f	7.5 mH
PV Input Power, P_{PV}	2.8 kW
Input Capacitor, C_{in}	2 mF
HBC Switching Frequency, f	50 kHz
HBC Output Filter, L_B	1 mH
Battery charge power, P_B	3.3 kW

Table II: Component Models Used For Loss Modeling Of The Proposed System

Component	Value
Diode, D	STTH6010W
ZSI MOSFETs [S_A, S_B, S_C and S_D]	APT28M120L
HBC MOSFETs [S_{AHB}, S_{BHB}, S_{CHB} and S_{DHB}]	APT28M120L
HBC Diodes, [S'_{AHB}, S'_{BHB}, S'_{CHB} and S'_{DHB}]	STTH6010W
Capacitor, C_{in}, C_1 and C_2	ECE-T2VP182FA

B. Loss Modeling

The misfortune demonstrating forthe proposed framework appeared in Fig.2 has beendone by displaying the real segments in PLECS 4.0. The exchanging parts utilized for the displaying is appeared in the Table II, For the misfortune demonstrating ofthe uninvolved segments, interior opposition of

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the inductors, L_1, L_2 and L_{fare} r=100 mω and the ESR, RHB for the capacitors C_1, C_2 and C_{in}

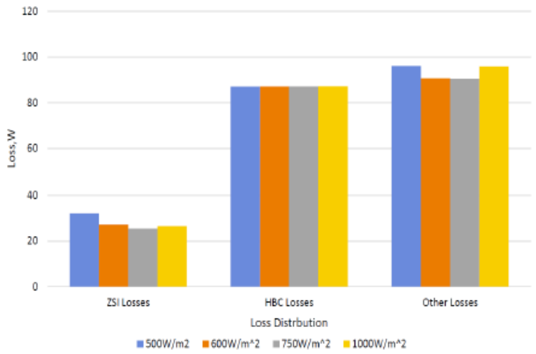

Fig. 9. Misfortune appropriation outline for influence P_B=3.3kWat25◦C, under shifting light

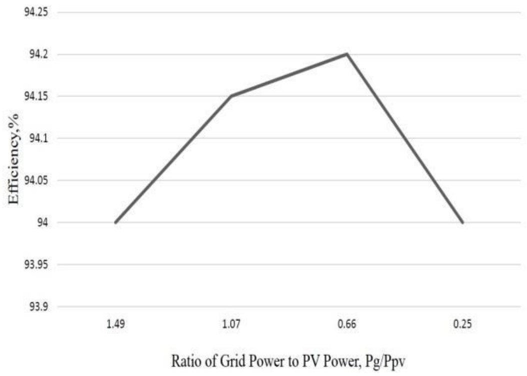

Fig. 10. Efficiency curve for different ratios of AC Grid Power $P_g$to Photovoltaic Power P_{pv}curve forafixed charging power P_B=3.3 kW at25 °Cundervarying irradiationare 138 mΩ.

Fig.9 demonstrates the misfortune circulation between the ZSI (conduction and exchanging misfortunes of diode D), the HBC (exchanging misfortunes ofthe MOSFETs and optional diodes)and different misfortunes in because of the inductor, capacitors, spillage misfortunes in the high recurrence transformer and battery arrangement protections in the framework for shifting lights for a consistent charging influence PB=3.3kW. Fig.10 demonstrates the effectiveness isaround 94% fromthe proficiency bend for different proportions of ACGrid Power,Pg, to Photovoltaic Power, Ppvfor a fixedchargingpower, PB=3.3 kW at 25 ◦C, for shifting light 500W/m2 to 1000W/m2. In spite of the fact that the productivity varieties is little, the effectiveness is the most elevated when the sharing between the photovoltaic power $P_{pv}$and the framework control P_{gis} equivalent. For a steady recurrence ofoperation, theHBC MOSFET misfortunes stay consistent fora fixed worth VB andcharging power,PB. In spite of the fact that as a general rule, this probably won't be the situation. The effectiveness ofthe converter willchangewith the adjustment in the battery voltage. Fig.11 demonstrates the dispersion ofthe misfortunes beween the ZSI losses,the HBCMOSFETs and the misfortunes due

Fig. 11. Misfortune circulation for different battery voltages,VB, for a fixed charging power,PB=3.3 kW, at 45 ◦C

Table III: Modified Z_{si} Based Charger System Prototype Electrical Specifications

Parameters	Value
Input Voltage, V_{in}	38 V
Input Current, I_{in}	3.82 A
Inductor Value, L_1 & L_2	500 uH
Peak DC Link Voltage, V_{PN}	63.33 V
Modulation Index, M	0.75
Shoot Through Duty Ratio, D_{0MAX}	0.2
Switching Frequency, F_{SW}	25 kHz
Grid Voltage, V_g	34 V(RMS)
Inverter Output Filter Inductor, L_f	2.5 mH
HBC switching frequency, f_{HBC}	50 kHz

to the inductor, misfortunes in the high recurrence transformer andbattery arrangement protections in the framework fordifferent battery voltages. From Fig.11,at 45 ◦C, the vpvdrops to 258V and it tends to be seen that with the expansion in battery voltage the ZSI misfortunes increment yet the HBC misfortunes and the misfortunes in the uninvolved parts diminish.

C. Experimental Verification of the MZSI power balance operation

In this paper as verification of idea, a downsized 175W test arrangement was assembled utilizing MATLAB/Simulink and

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dSPACE 1103.The arrangement has the accompanying particulars appeared in table III.

Fig. 12 demonstrates the PWM conspire for the HBC. Every one of the split essential work for a large portion of the HBC exchanging period.

Each MOSFET SAHB, SBHB, SCHB and SDHB works solely for one fourth of the whole HBC exchanging period. Condition (23) can be written as far as the present

$$i_{PV} = \frac{1-D_0}{2(1-2D_0)} i_b + \frac{M}{\sqrt{2}(1-2D_0)} i_g \qquad (21)$$

where M is the modulation index and D_0 is the shootthroughduty ratio. For D_0=0.2,

$$i_{PV} = \frac{2}{3} i_b + \frac{\sqrt{3}}{2} i_g \qquad (22)$$

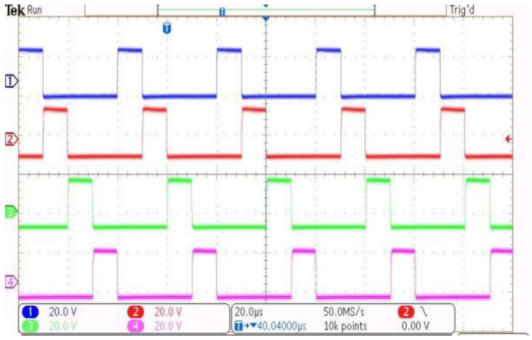

Fig. 12. PWM logic for the isolated HBC

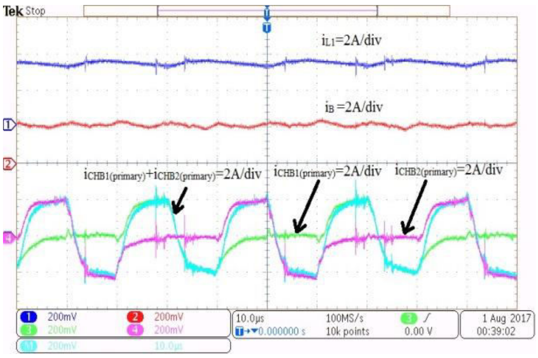

Fig. 13. Experimental setup waveforms for the Inductor current(top), charger output current(middle) andtheprimary currents of the splitcharger(bottom)From equation (22), at D_0=0.2, foraninputcurrent i_{PV}=3.82 A and fixed HBC output current i_b=2 A, the ZSI ACoutputcurrent $i_g$is calculated to be2.87A.

From condition (22), at D0=0.2, foran info current iPV =3.82A and fixedHBC yield current ib=2 A, theZSI AC outputcurrent ig is determined to be 2.87 A.

Fig.13 demonstrates theinductorcurrent iL1, the battery currentiB and thesplit essential current iCHB1 and iCHB2 and thetotal essential current. Every one of the essential work alternately.The all out essential current is a high recurrence alternatingcurrent of fHBC=50 kHz.From Fig. 13 and Fig. 14, the charger ouput current ismaintained at 2 An utilizing a ChromaProgrammable AC/DCElectronics Load(Model 6304). The PV input current is maintainedat 3.82 An utilizing a Magna-control LXITM sun powered emulator.The yield framework current is seen to be 2.66 A. Fig. 15 showsthe trial arrangement for the confirmation of idea. The lower estimations of the yield current is an aftereffect of thelosses in the circuit. The useful PI esteems for the ACside current control was KP =0.03 and the battery circle wasKPB=.0003 and KIB=.09 and the information PV current circle wereKPin=0.005 and KIin=2.

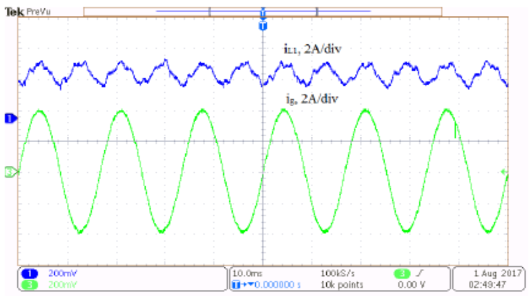

Fig. 14. Test waveforminput current(blue) and yield current(green)between the charger andtheAC yield of theMZSI

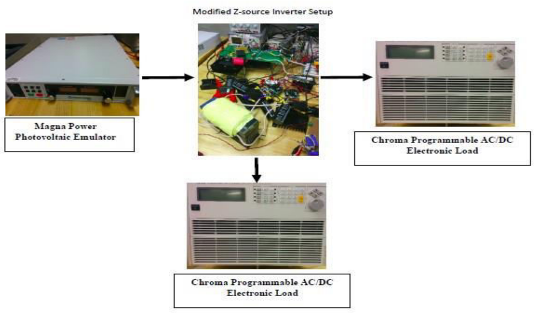

Fig. 15. Experimental setup

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Table IV: Isolated HalfBridge Dc-Dc SystemElectricalSpecifications

Parameters	Value
Input Voltage, V_C	50.667 V
Output Voltage , V_B	25.335 V
Switching Frequency, $F_{sw(HB}$	50 kHz
Filter inductor, L_B,	330 uH

V. CONCLUSION

A changed ZSI topology has been proposed inthispaper is an alluring answer for photovoltaic matrix associated charging frameworks. It comprise ofa solitary stage photovoltaic lattice (PV-Grid) association and a coordinated charger for PV-Grid associated chargingor vitality stockpiling. This topology canbe connected to brought together setup forchargingin semi-business areas, for example, a parking area of a shopping center. For private applications,this thought can be reached out to stringinverters with thecharger side of the string inverter designs associated in arrangement or parallelfor current sharing.

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