iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VII Month of publication: July 2022

DOI: https://doi.org/10.22214/ijraset.2022.43821

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

EV Charging Schemes With Different Bidirectional DC-DC Converters

Saurabh S. Kande[1], Priyanka R. Khade[2], Manjiri M. Tamhankar[3]
[1, 2, 3]Department of Electrical Engineering, Walchand College of Engineering, Sangli – 416415, Maharashtra, India.

***Abstract:** In electrical vehicle, galvanic isolation for dc-dc converters are often utilized. Basically these converters are connected between your dc link and storage element. So to achieve high density in power, high efficiency with wide range of gain and bidirectional capability of power flow CLLC and Dual active bridge are most suitable for all purposes to meet. Therefore this study based on the CLLC and Dual active bridge converters. This paper also focuses on grid connected AC - DC converter and controlling DC link voltage and then collectively designing the suitable charging scheme which will be able to deliver power in both directions. The operation and control methods of these converters are explained respectively.*
Simulation and its findings are used to verify the correctness of the suggested notion
***Keywords:** Synchronous reference frame theory, AC-DC converter, Bidirectional DC-DC Converter, DAB converter, CLLC converter*

I. INTRODUCTION

The problem of pollution, climate changes, fuel depletion, rising fuel prices are the primary reasons of growth of electric vehicle.[1] So lot of work is going on technics to improve performance, efficiency, bidirectional power transfer capability and power density of electric vehicle charger.[1]. In electric vehicle charger scheme, basically there are two stages. one is ac -dc transformation and other is dc to dc transformation.[1] So here we are making use of Synchronous reference frame theory to get control over dc link voltage which is output of 3-ph PWM converter. BDCs are praised for their focus on eliminating switching losses, reducing EMI, and achieving achievable high frequency operability, thus achieving power density without sacrificing efficiency. The three-phase AC-DC PWM converter may function with any DC voltage reference value. This reference value can be changed to any value you like. We made use of feedback control to obtain the intermediate circuit voltage and compare it to the reference voltage. After comparison from controller the error signal generated with the help of reference value and the set value is sent to turn on or OFF the six gates of the converter. Power transmission can be taken in and out of power depending on the DC link voltage. When we have a positive DC voltage, this is known as rectifier functioning, and the capacitor will discharge. To acquire additional power from AC electricity, this bug necessitates the control of blocks. To generate the necessary PWM signal, the controller received currents from the source. More current flows from the AC side to the DC side in this manner. Negative direct current, on the other hand, causes inverter operation, which causes the capacitor to be overcharged. The control circuit must discharge the capacitor in response to the error signal. Not only can PWM control manage active power, but it can also manage reactive power.
This output is then transferred to dc -dc converter and through this it is supplied to energy storage element (Battery).
To control the switching of both ac -dc and dc -dc converter SPWM control is adapted. The main manuscript of this paper is we are implementing two different categories of dc -dc converter and analyzing the performance of charging scheme. These two dc-dc converters are DAB Converter and CLLC resonant Converter which are mostly used to design electric vehicle charging scheme. This dc -dc converter interlinks the dc link voltage and energy storage unit like Battery. The chosen battery is Lithium-ion type and has following ratings:

1) Battery Energy : 100 kwh
2) Battery voltage: 350 volts
3) Battery capacity: 286 Ahr

II. CONTRIBUTION AND ORGANISATION OF PAPER

This paper discusses the DAFB and CLLC converters used in charging system of EV which is bidirectional in nature. It also gives a approach to working and control scheme applied to the DAFB. The suggested DAFB and CLLC model, as well as its control approaches, are developed and evaluated in Matlab/Simulink for both G2V and V2G operations. This paper is structured in following way: Section 3 presents an overview of Synchronous reference frame theory and it's implementation; Section 4 tells about the DAB converter approach; Section 5 explains about CLLC resonant converter; Section 6 is about the simulation and experimental results; finally, Section 7 will arrive at conclusion.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

III. SYNCHRONOUS REFERANCE FRAME

SRF is based on the dq frame, which is a time domain approach generated from a threephase system's spatial vector transformation. The Park transformation is used to convert a three-phase coordinate system of currents to a two-phase Cartesian coordinate system that spins at a particular velocity, based on the SRF fundamental dq frame theory. Current harmonics with an angular frequency equal to the rotation speed of the dq frame cause a DC component. Because of current harmonics with an angular frequency, DQ AC components are different from the rotation speed of the frame. [5] The voltage-directed technique is based on a series of transformations from ABC, a three-phase quiescent coordinate system, to dq, a synchronous rotating coordinate system, via ABC, a two-phase quiescent coordinate system. The control voltage remains constant and becomes DC as a result of these conversions, making the entire control process easier.[4] The theoretical aspects of VOC technology used in grid tie rectifiers are explained in detail. The PWM scheme is colaborate with the control strategy used to make sure that the characteristics of the VOC control system changes. The effect of noise also minimized. Changes in switching frequency is the main cause to the resulting power switching stress and loss. For reducing this you will need an input filter with high quality parameters. To reduce harmonic problems, the stated scheme applies VOC principles to get control over the charging process while maintaining less harmonic distortion in the circuitb by using the conversion technology, the control variable on the AC side becomes a DC signal. Also steady-state errors can be terminated with the help of corresponding proportional integral (PI) controller. [7]

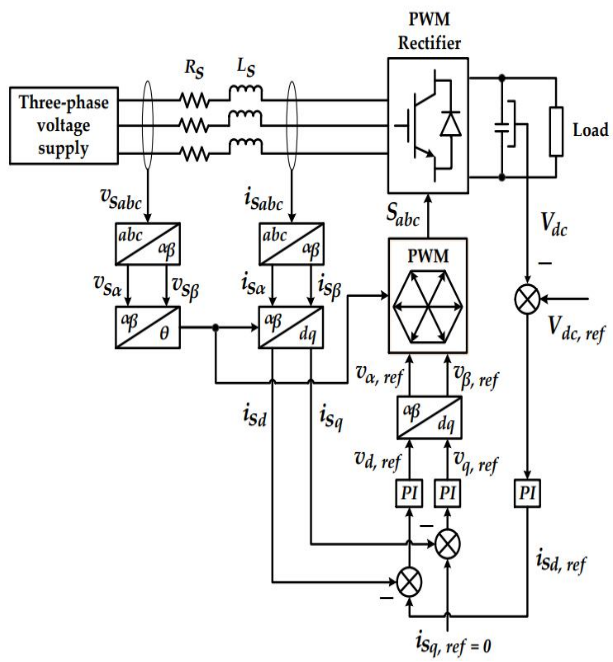


Fig.1 control scheme to maintain DC-link voltage constant

$$vd,ref = Kp(isd,ref - isd) + Ki \int (isd,ref - isd)dt$$

$$vq,ref = Kp(isq,ref - isq) + Ki \int (isq,ref - isq)dt$$

where Kp and Ki are the PI controller gains, isd and isq are the dq0 domain currents and isd,ref and isq,ref are the reference signals for isd and isq respectively. After obtaining the reference voltage vd,ref and vq,ref the inverse Park transformation applied along with the PWM switching technique to obtain the gate switching pulses for Sabc (three phase reference voltage), which in charge of the VOC rectifier's operation. The total shift that is currently going place are shown in Figure 1.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

A. Proposed Design Of Srf Controller

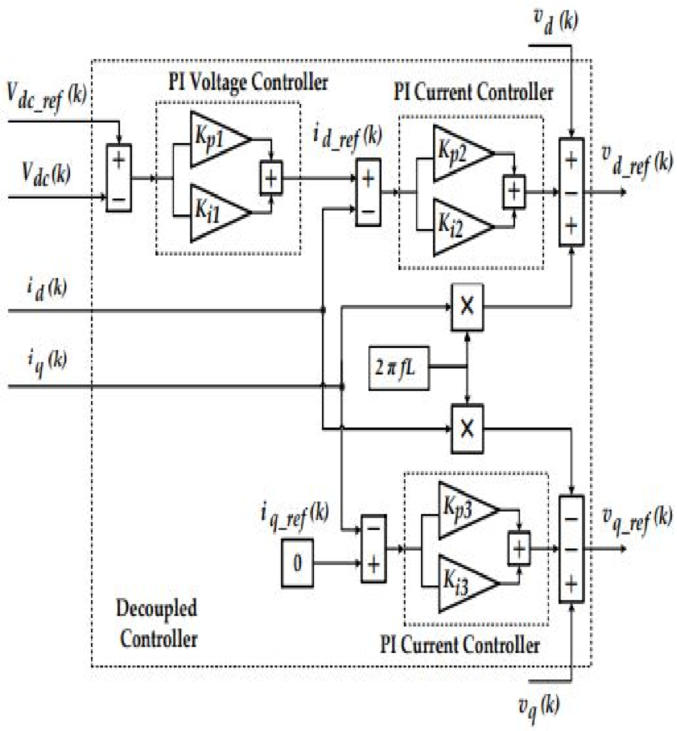


Fig. 2 Internal design of SRF control

In this control process must first convert the three-phase AC power into an alpha-beta component of voltage and currents. After that, the separated active and reactive components are regulated to reduce the difference between the required reference and measured active and reactive component values. In general, a DC link voltage control strategy is used to tune the active current component ID in order to achieve active power flow balance in the system. On the other hand, the invalid power factor iq is adjusted to 0 to guarantee the operation of power factor 1.

The outputs of the isolated controller are Vd and Vq. To reduce error PI controller is used. The integral operation terminates the error only when we have constant steady-state reference value. By using the Clark and Park conversion method, obtained currents are converted to DC magnitude. Then you can get good results with a simple PI controller. The error is calculated by comparing the reference signal to the observed system output and applying error to the PI controller we will be generating output signal. A PI controller's sole purpose is to calculate the desired DC link voltage by comparing the instantaneous and reference voltages. The DC link voltage is then used to calculate the reference current Id, which is needed to keep the DC voltage constant. Making the current Id equal to zero yields the power factor equal to 1. AS Id becomes zero, the reactive power goes to zero and unity power factor is obtained. Current control is performed to get the reference current in the system. The resulting reference voltage current control is calculated by the d-q axis method. The control scheme two PI control loops are simulated with first is for id and second is for iq component. The outputs from the two PI controller, are v_d^* and v_q^*.

$$v_d^* = E_d - k_p \in d \quad k_p \frac{\epsilon_d}{s} + wLIq$$

$$v_q^* = Eq - k_p \in q - k_p \frac{\epsilon q}{s} + w_{LId}$$

Error which should be given to the controller is achieved as follows:

$\epsilon = v_d ref - v_d$

By using PI controller the current reference for system as i_d^* can be obtained as follows:

$$i_d^* = k_p \cdot \epsilon + k_i \, {}^{\epsilon}/_{s}$$

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

IV. BIDIRECTIONAL DAB CONVERTERS

In figure the schematic of Dual Active Bridge converter is shown. Two complete bridges are used in the circuit, which are isolated using a high frequency transformer and also has tank circuit. This high frequency transformers gives the required separation between EVs and the power grid and between EV's in the charging infrastructure that can charge multiple vehicles at the same time. Inductance and semiconductor drive are used to transfer the required power. This inductance can be matched with the corresponding leakage inductance of the transformer in high frequency systems. The DAB is a bidirectional isolated DC-DC converter that can buck and boost. It's especially well-suited to controlling high power conversion efficiency and voltage management throughout a broad range of input and output voltage changes.

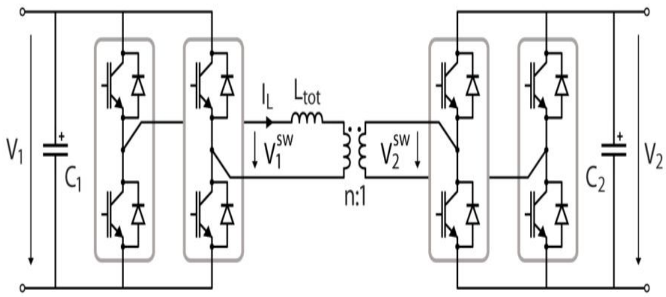
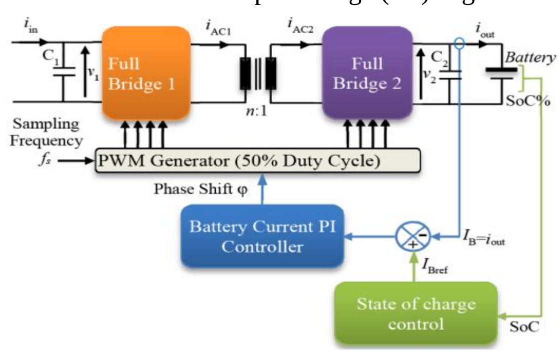


Fig.3. DAB converter switching Circuit

The DAB's H bridge operates to get voltage square waves of high frequency at the terminals of the transformer. The H bridge has two sides, one of which is a DC/AC converter and the other is an AC/DC converter. The flow of electricity from the converter is controlled by altering the phase shift (Φ) between the two square waves. Power is always transferred from the bridge that generates the leading square wave to the other bridge. By adapting the phase shift, the power flow occurs from V1 to V2 and vice versa. In this application, DAB operates in power control mode. The DAB's output voltage is always kept at the reference level even if the output current and the input voltage (V1) fluctuate. A constant output voltage (V2) is given as an input to the DC-DC converter.



Following are the parameters chosen while designing the DAB converter and same parameters are used while simulation and all results are respective to these parameters only.

Parameters	Values
Nominal Power	$50e^3$ VA
Nominal Frequency	$20e^3$ Hz
Magnetization Inductance	$1.76e^{-3}$ H
Magnetization Resistance	$10e^3$ OHM
V1(Vrms)	300 V
R1	4.35e-3 ohm
L1	3.32e-6 H
Input capacitor	7e-3 F
Output capacitor	22e-3 F

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

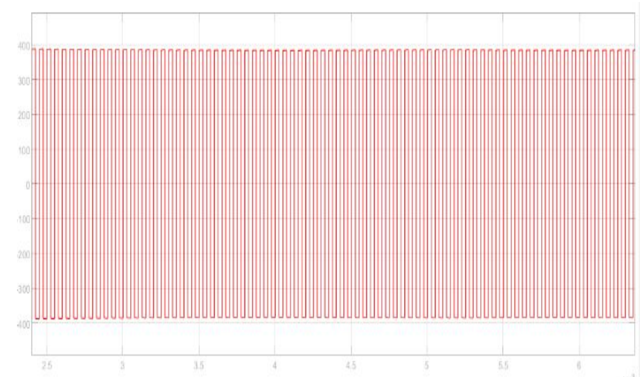


FIG. A WAVEFORM AT PRIMARY SIDE OF DAB

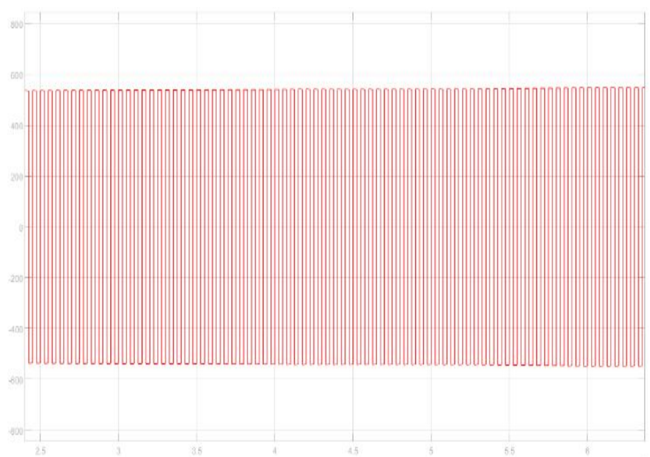


FIG. B WAVEFORM AT SECONDARY SIDE OF DAB

V. BIDIRECTIONAL CLLC CONVERTER

So this is basically a CLLC resonant converter looks like.

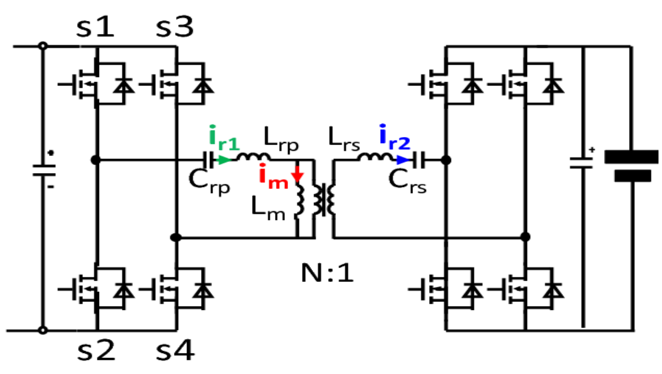


Fig.4.CLLC converter switching Circuit

It is equipped with a symmetrical full-bridge structure. On primary side which is basically inverting stage it has symmetrical high-frequency transformer and on the secondary it is rectification stage. On primary side as it is inverting stage power conversion from AC to DC takes place and then transferred to secondary via transformer. With this transformer, between the primary and secondary sides galvanic isolation for converters is simple to accomplish. The transformer's magnetization inductance is Lm and a transformer turns ratio of 1: 1.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

The resonant inductors Lrp and Lrs obtained by combining the leakage inductances of the transformer's primary and secondary windings. Automatic flux equilibrium obtained with the help of resonant capacitors Crp and Crs and high resonant frequency with the help of Lrp and Lrs.
Following are the parameters chosen while designing the CLLC converter and same parameters are used while simulation and all results are respective to these parameters only.

$$L_m \leq \frac{t_{do}}{16 \cdot C \cdot F_s}$$

$$F_{sr} - \frac{1}{2\pi\sqrt{L_s \cdot C_s}}$$

C_{rp}	7.3e-9 F
L_{rp}	120.2e-6 H
C_{rs}	16.4e-9 F
L_{rs}	53.4e-6 H
L_m	480.8e-6 H
Input capacitor	7e-3 F
Output capacitor	22e-3 F

A. Operation principle of CLLC

It has following operating stages: [1] Resonance stage
[2] Non resonance or discontinuous [3] Dead time of capacitor charge/discharge stage [4] Dead time with diode freewheeling stage

1) *Resonance Stage:* On the primary side, when the switches S1 and S4 are on, the resonant current iL increases in a sine wave form via s1 and s4, and the chopping voltage Vin increases. Power is transferred from the primary side to the load at the same time. Also the output voltage clamps the Lm which is in parallel with the transformer, so it behaves as a passive load and stays away from resonance. During this phase, the current flowing through the magnetization inductance iLm grows in a triangle and becomes smaller than iLs. Due to the voltages on the secondary side of the transformer, the diodes of switches S5 and S8 become biased in the forward direction, allowing current to flow from the rectifier bridge to the output battery. The ILm meets the resonant current ILs at the end of this stage.
2) *Non Resonance or Discontinuous Mode:* During this the inductance current iLm starts decreasing and at some point of time it equals to value of iLs, and net current which flows through the transformer becomes zero and on the secondary side also rectifier current comes to zero. Magnetized inductors, along with series capacitors and series inductors, predict resonance. The Cs2 on the secondary side reaches its peak and does not change because the rectified current is zero there. In the zero current switching mode, the diodes of the switches S5 and S8 are switched off. This stage is called discontinuous operation because the rectifier current is no longer continuous. During this time, no power transfer will be transferred from primary to secondary sides.
3) *Dead time Capacitor Charging/discharging Stage:* The switches S1 and S4 are conducting throughout this operation stage, and the parasitic capacitors are entirely depleted. After a while, the switches S1 and S4 are turned off, and iLs remains constant in terms of flow direction. As a result, the parasitic capacitors of S1 and S4 begin to charge, while the parasitic capacitors of S2 and S3 begin to discharge at the same time. Because the parasitic capacitor has a lower rating than the series capacitor Cs, the charging/discharging time is excessively short in comparison to the full switching cycle.
4) *Dead time with Diode Freewheeling Stage:* During this stage, the parasitic capacitors of switches S1 and S4 are fully charged, while those of switches S2 and S3 are fully discharged, and the resonant current begins to pass through the antiparallel diodes of switches S2 and S3, ensuring zero voltage switching for the next stage's turn on events. In comparison to the complete switching cycle, this period is also far too short.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VII July 2022- Available at www.ijraset.com

VI. SIMULATION RESULTS

The simulation work is done with the help of MATLAB/SIMULINK software. The graphs in the following section represents all the results obtained for different parameters at different stages and conditions of simulation. Battery, AC-DC converter, SRF controller, Bidirectional DC-DC DAB converter, and Bidirectional DC-DC CLLC Resonant converter are the key components of the simulation. All the results specified below are verified with the help of simulation.

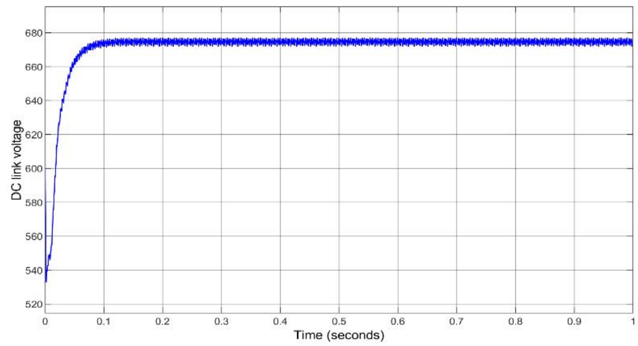


Fig1. DC Link Voltage

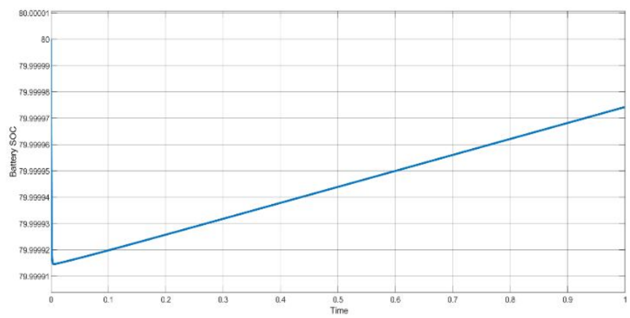


Fig2. Battery SOC during charging

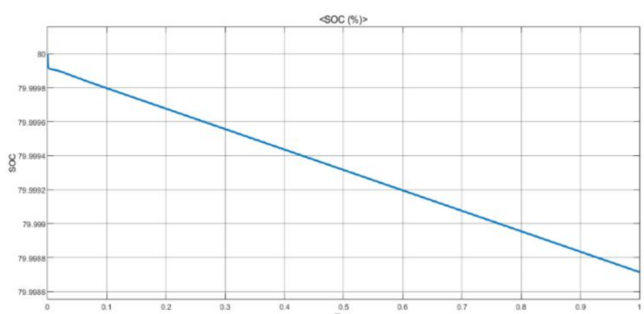


Fig3. Battery SOC during charging

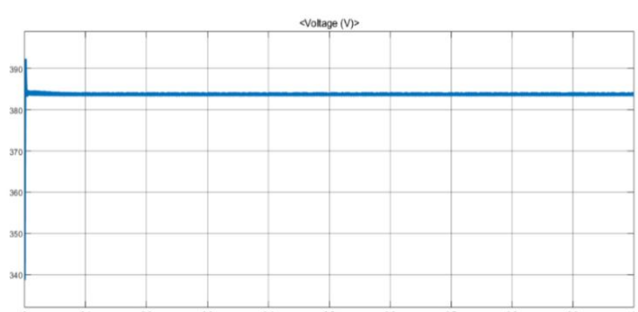


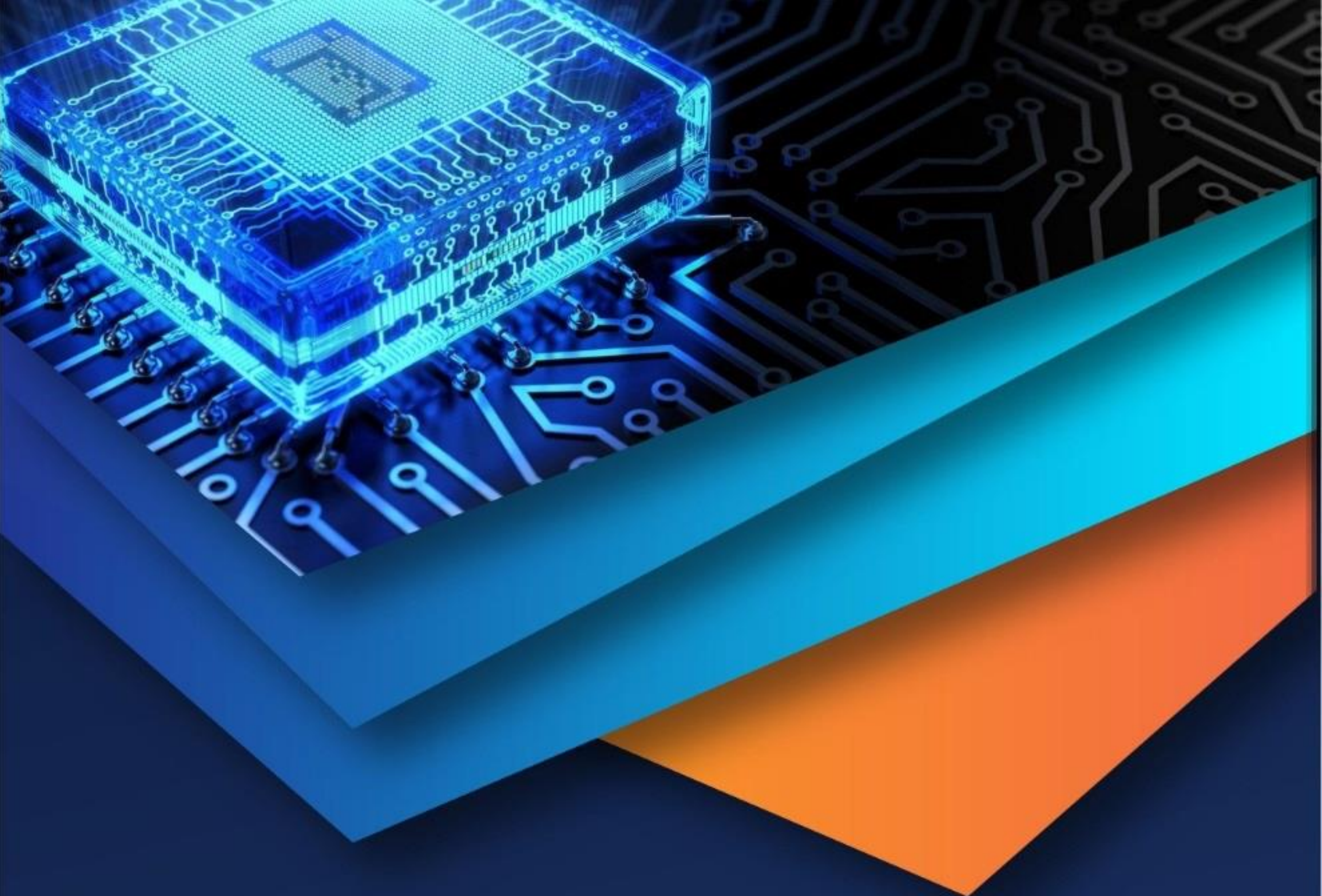
Fig4. Battery voltage

VII. CONCLUSION

This paper gives the detail information about synchronous reference frame concept. Then we saw that how we can implement this SRF concept along with PI controller to obtain a constant DC link voltage at the output of converter. In section IV we saw the waveform across both primary and secondary of dual active bridge converter which are pure square wave which means the proper working of converter and power transfer is achieved. In further stages, this paper also gives detail idea about working and implementation of DAB and CLLC converter. After simulating, we got the results in terms of SOC of battery during charging and discharging. As we can see in the section VI fig 2 during charging operation the SOC of battery is increasing as battery start charging and during discharging the battery SOC starts decreasing. Also we got the constant battery voltage which is almost near about the battery voltage.

REFERENCES

[1] Al-Ogaili, A. S. et al. A three-level universal electric vehicle charger based on voltage-oriented control and pulse-width modulation. Energies (Basel) **12**, (2019).
[2] IEEE Staff & IEEE Staff. 2010 IEEE Applied Power Electronics Conference and Exposition.
[3] Al, T. M., Lyu, D., Soeiro, T. B. & Bauer, P. Design of a Wide Output Voltage Dual Active Bridge Converter as Power Electronics Building Block for the Fast Charging of Electric Vehicles. in Proceedings - 2021 IEEE 19th International Power Electronics and Motion Control Conference, PEMC 2021 89–96 (Institute of Electrical and Electronics Engineers Inc., 2021).
[4] He, P. & Khaligh, A. Comprehensive Analyses and Comparison of 1 kW Isolated DC-DC Converters for Bidirectional EV Charging Systems. IEEE Transactions on Transportation Electrification **3**, 147–156 (2017).
[5] Chen, W., Rong, P. & Lu, Z. Snubberless bidirectional DC-DC converter with new CLLC resonant tank featuring minimized switching loss. IEEE Transactions on Industrial Electronics **57**, 3075–3086 (2010).
[6] Jarraya, F., Khan, A., Gastli, A., Ben-Brahim, L. & Hamila, R. Design considerations, modelling, and control of dual-active full bridge for electric vehicles charging applications. The Journal of Engineering **2019**, 8439–8447 (2019).
[7] Institute of Electrical and Electronics Engineers et al. 2014 International Conference on Applied and Theoretical Electricity (ICATE) : proceedings : October 23-25, 2014, Craiova, Romania.
[8] Liu, C. Analysis, Design and Control of DC-DC Resonant Converter for On-board Bidirectional Battery Charger in Electric Vehicles. (2017).
[9] Nasir, A., Hamad, M. S. & Elshenawy, A. K. Design and Development of a Constant Current Constant Voltage Fast Battery Charger for Electric Vehicles.
[10] Lechat Sanjuan, S. Voltage Oriented Control of Three-Phase Boost PWM Converters Design, simulation and implementation of a 3-phase boost battery charger Master of Science Thesis in Electric Power Engineering.
[11] B. Whitaker et al., “A high-density, high-efficiency, isolated on-board vehicle battery charger utilizing silicon carbide power devices,” IEEE Trans. Power Electron., vol. 29, no. 5, pp. 2606–2617, May 2014
[12] Hedlund, Magnus. "Design and construction of a bidirectional DC-DC converter for an EV application." (2010).
[13] L. Xue, Z. Shen, D. Boroyevich, P. Mattavelli and D. Diaz, “Dual active bridge-based battery charger for plug-in hybrid electric vehicle with charging current containing low frequency ripple,” IEEE Trans. Power Electron., vol. 30, no. 12, pp. 7299–7307, Dec. 2015.
[14] Miranda UA, Rolim RGB, Aredes M, “A DQ Synchronous Reference Frame Control for Single-Phase Converters”, Power Electronics Specialists Conference, 2005, pp 1377-1381, ISBN 0-7803-9033-4.
[15] Xuan, Z., Shenghua, H., Guoyun, N.: ‘A three-phase dual active bridge bidirectional ZVS DC/DC converter’, Phys. Procedia., 2012, 24, pp. pp. 139– 148



INDEX COPERNICUS

10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY