International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST

Implementation of Zero Current Switching for High Step-Up Full Bridge Isolated DC-DC Converter with Multi-Cell Diode Capacitor Network

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ARTICLEINFO

Article History:

Accepted: 01 April 2023
Published: 20 April 2023

Publication Issue
Volume 10, Issue 2
March-April-2023

Page Number
687-696

ABSTRACT

In this paper, implementation of zero current switching for high step-up full bridge isolated dc-dc converter with multi-cell diode capacitor network. The converter's is used to increase the low input voltage to a higher output voltage that can be used in a variety power application. The proposed network consists of a boost converter and a ZCS realization circuit that regulates the output voltage by adjusting the duty cycle of the boost converter. The results demonstrate that the proposed converter provides a high step-up ratio and a stable output voltage with low ripple. It has the following advantages increases voltage boost capability and avoid extreme large duty ratio, achieves almost zero output voltage ripples, reduces transformer turns ratio. furthermore, zero current switching (ZCS) Realization helps in increases the efficiency and decreases the switching losses which caused by the voltage stress and distortions. The PI controller results provides a high step-up ratio and a stable output voltage with low ripple. The closed-loop control system also shows excellent dynamic performance with fast response to load and input voltage changes. Overall, the proposed converter offers an efficient and reliable solution for high voltage applications.

Keywords : Isolated Boost Converter, PI Controller, Multi-Winding transformer, Diode-Capacitor Network, Zero-Current Switching.

I. INTRODUCTION

The establishment of sunlight based and power device is more rapidly use in Future. Hybrid electric vehicles, more electric ships, and more electric aircraft could all benefit from future power supply systems based on fuel cells and lightweight batteries. However, for the dc sources input is low voltage supply and output is high voltage supply and these circuit consists of the parasitic parameters of the circuit [1]. A high voltage capacity for power converters with low input voltage and high proficiency in Fig.1, these are oftentimes utilized in medium-and high-power applications because of inherent advantages [3][4]. To increment yield voltage, a voltage doubler rectifier is utilized instead of the optional side in Fig.2 [5]. The voltage support proportion is displayed here. Which is more proficient and successful for accomplishing high voltage gain with high effectiveness and high power. current. Because of the diode-capacitor circuit's high inrush current, Fig. 3(b) likewise requires a low pass channel. To explore the troubles of spillage inductance and thorough LC channel necessities, this paper recommends a high move forward full-span disconnected DC converter with a multi-cell diode-capacitor network that utilizes the upsides of a multi-winding transformer and a diode-capacitor voltage support cel[6]-[9]l. In this paper, implementing of zero current switching with high step-up full bridge isolated DC_DC converter with multi cell diode capacitor network.

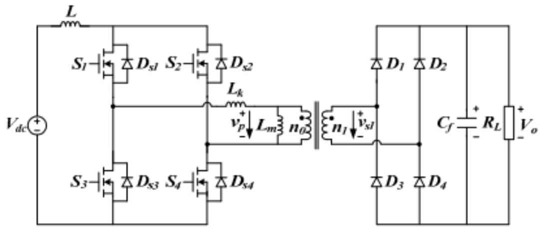


Fig.1 Full-bridge isolated boost DC-DC converter with diode rectifier

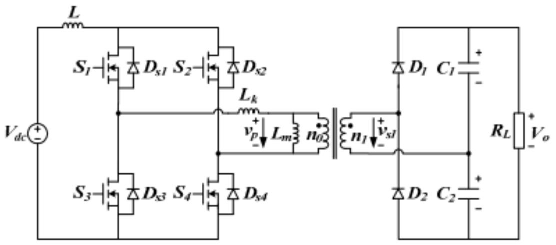
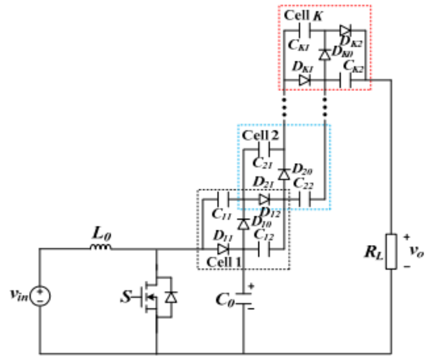


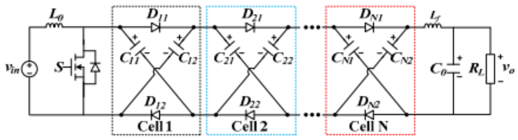
Fig.2 Full-bridge isolated boost DC-DC converter with voltage doubler rectifier

The problem with inrush current is avoided, and output voltage ripples are practically eliminated. The ratio of transformer turns and the volume of magnetic components both decrease while a high-power density is generated.



(a) Series connection of multi-cell diode-capacitor network.

(b)



(c) Cascade connection of multi-cell diode-capacitor network.

Fig.3 High step-up DC-DC converters with multi-cell diode-capacitor network.

II. SYSTEM DESCRIPTION

A. Operation:

Figure 4 illustrates a simple voltage boost cell consisting of a two-port diode-capacitor network. By connecting C_{11} and C_{12} in parallel and allowing D_{11} and D_{12} to conduct, the cell can achieve the desired terminal voltage.

$$V_2 = V_{C_{11}} = V_{C_{12}} = V_1 \qquad (1)$$

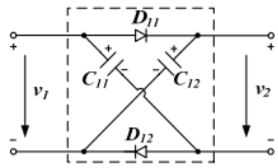


Fig.4 Essential diode-capacitor voltage support cell

The terminal voltage is met by blocking D_{11} and D_{12} in the opposite direction and connecting C_{11} and C_{12} in series.

$$V_2 = V_{C_{11}} + V_{C_{12}} - V_1 \qquad (2)$$

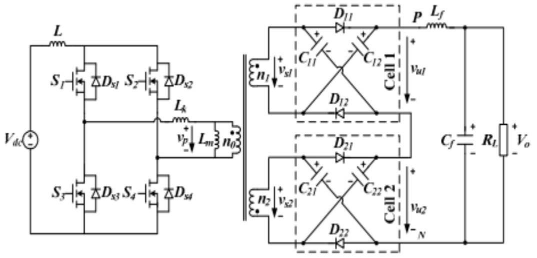


Fig.5 a two-cell diode capacitor network in a full-bridge isolated DC–DC converter with high step-up.

The referenced full-bridge disconnected, two-cell diode-capacitor network high move forward DC converter is shown in Fig.5. The attractive and spillage inductors L_m and L_k can be combined in equal measure to differentiate the high-recurrence transformer from an ideal transformer.

The boost inductor L and DC source Vdc are coupled in series to charge the essential side of the transformer when S_1=S_4=ON, S_2=S_3=OFF.

$$L\frac{di_L}{dt} = V_{dc} - v_{p(S1=S4=ON)} \quad (3)$$

The transformer's secondary side voltage (V_{S_1}, V_{S_2}) complies with the following:

$$V_{s1(S_1=S_4=ON)} = \frac{n_1}{n_0} v_{p(S_1=S_4=ON)} \quad (4)$$

$$V_{s2(S_1=S_4=ON)} = -\frac{n_2}{n_0} v_{p(S_1=S_4=ON)} \quad (5)$$

D_{11} and D_{12} are conducting, and the induced voltage V_{S_1} is positive. The two capacitors, C_{11} and C_{12}, are parallel-charged by the n_1 winding.

$$v_{u1(S_1=S_4=ON)} = V_{C11} = v_{s1(S_1=S_4=ON)} \quad (6)$$

Due to the negative inductive voltage, D_{21} and D_{22} are blocked (V_{S_2}). The n_2 wind is connected in series with the two capacitors C_{21}, C_{22} to power the output side.

$$v_{u2(S_1=S_4=ON)} = -v_{s2} + 2V_{C21} \quad (7)$$

$$v_{PN(S1=S4=ON)} = v_{u1(S_1=S_4=ON)} + v_{u2(S_1=S_4=ON)} = 2V_{C21} + \frac{n_2}{n_1}V_{C11} + V_{C11} \quad (8)$$

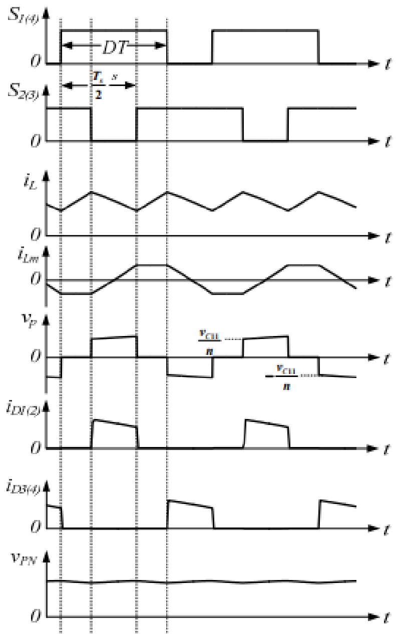


Fig.6 Operation principle of high step-up full bridge isolated DC-DC converter with two-cell diode-capacitor network.

During the S_1=S_4=S_2=S_3=ON interval, the transformer primary side winding n_0 is shorted, and V_P=0. Using the DC source V_{dc}, the boost inductor is charged.

$$L\frac{di_L}{dt} = V_{dc} \quad (9)$$

During this time, the voltage on the transformer's secondary side is equal to zero. The transformer's D_{11}, D_{12}, D_{21}, and D_{22} diodes are all completely blocked on the secondary side. The secondary side windings n_1 and C_{11}, C_{12}, n_2 and C_{21}, C_{22} are linked in series to supply the output side of the transformer. The output voltage is before filtering

$$V_{PN(S_1=S_2=S_3=S_4=ON)} = 2V_{C_{11}} + 2V_{C_{21}} \quad (10)$$

To charge the transformer's primary side backwards during the S_2=S_3=ON, S_1=S_4=OFF period, the boost inductor L is connected in series with DC source V_{dc}. boost inductor current that is linearly decreasing

$$L\frac{di_L}{dt} = V_{dc} + v_{p(S_2=S_3=ON)} = V_{dc} - \frac{n_0}{n_2}V_{c21} \quad (11)$$

The induced transformer has a negative secondary side voltage, or V_{S_1}. D_{11} and D_{12} blocks are available. C_{11} and C_{12} are coupled with the n_1 winding in series to supply the output side.

$$v_{u1(S_2=S_3=ON)} = v_{s1(S_2=S_3=ON)} + 2V_{C11} = \frac{n_1}{n_2} v_{s2(S_2=S_3=ON)} + 2V_{C11} \quad (12)$$

Positive voltage V_{S_2} is present on the secondary side of the induced transformer. D_{21} and D_{22} are used in conducting. By using the n_2 winding, two capacitors, C_{21} and C_{22}, are simultaneously charged. The $V_{C_{21}}$ snares the V_{S_2}.

$$v_{u2(S_2=S_3=ON)} = V_{C21} = -\frac{n_2}{n_0} v_{p(S_2=S_1=ON)} \quad (13)$$

The output voltage is lower when there is a switching state because

$$V_{PN(S_2=S_3=ON)} = 2V_{C11} + \frac{n_1}{n_2} V_{C21} + V_{C21} (14)$$

The boost inductor L's average voltage should be zero during a switching time period T_s during steady state. The combined effects of (3), (9) and (11)

$$\left(V_{dc} - \frac{n_0}{n_1} V_{C11}\right)(1-D)T_s + \left(V_{dc} - \frac{n_0}{n_2} V_{C21}\right)(1-D)T_s + V_{dc}(2D-1)T_s = 0 (15)$$

By solving the preceding equation as follows, the voltage of the intermediate capacitor can be found.

$$(1\text{-D})\left(\frac{n_0}{n_1} V_{C11} + \frac{n_0}{n_2} V_{C21}\right) = V_{dc} \quad (16)$$

If two secondary side windings have the same turns ratio, then all of the intermediate capacitors in the secondary side of the transformer will have the same voltage. (16).

$$V_C = \frac{n}{2} \cdot \frac{1}{1-D} V_{dc} \quad (17)$$

According to (8), (10), (14) and (16), v_{pn} has the same voltage and is nearly constant (17).

$$V_C = \frac{n}{2} \cdot \frac{1}{1-D} V_{dc} \quad (18)$$

In steady state, switches S_1, S_4, or S_2, S_3 contain the highest value of the transformer primary side voltage, or V_P. From (17), it can be concluded that:

$$v_{p(S_1=S_4=ON, S_2=S_3=OFF)} = \frac{n_0}{n_1} V_{C11} \frac{1}{2} \cdot \frac{1}{1-D} V_{dc} \quad (19)$$

Every diode is confronted to the same voltage stress. The voltage across D_{11} and D_{12} during the S_2=S_3=ON, S_1=S_4=OFF period is produced by the reversed connection with $V_{C_{11}}$ and V_{S_1}. The conclusion is that:

$$v_{S_{Diode}} = v_{C11} - v_{s1(S_2=S_3=ON)} = \frac{n}{1-D} V_{dc} \quad (20)$$

A high step-up full bridge isolated DC-DC converter with additional two-port diode-capacitor cells (N=2k) can achieve even greater voltage gain. Fig.7 depicts the primary circuit, and the voltage gain and voltage stress of a switch and diode can be expressed using equations (21), (22), and (23), which were derived using a similar method (23).

$$G = \frac{v_0}{V_{dc}} = \frac{N.n}{1-D} \quad (21)$$

$$v_{s\_Mos} = \frac{1}{2}\frac{1}{1-D} V_{dc} = \frac{G}{2N.n} V_{dc} \quad (22)$$

$$v_{s\_Diode} = \frac{n}{1-D} V_{dc} = \frac{G}{N} V_{dc} \quad (23)$$

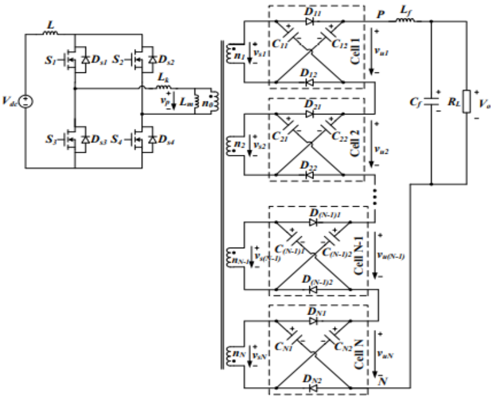


Fig.7 Full-bridge isolated DC-DC converter with high step-up and a multi-cell diode capacitor network

B. ZERO CURRENT SWITCHING (ZCS) REALIZATION:

Because of the leakage inductor in the transformer, the switching devices are subjected to high voltage stress and spikes. To absorb leakage energy and reduce switching loss, a ZCS resonant circuit with L_K and C_r is provided. It regulates the secondary side diodes' turn-off d_i/d_t and reduces voltage spikes [5] [10]. Figure 8 shows a ZCS resonant high-step full-bridge isolated DC-DC converter with a two-cell diode-capacitor network (N=2). Fig.12 depicts the primary waveforms at various intervals during steady state.

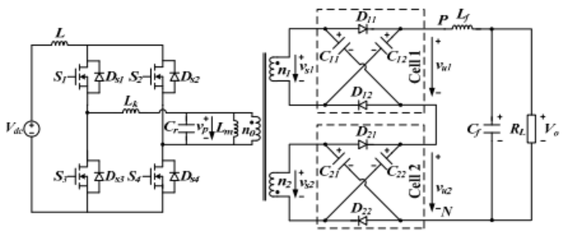


Fig.8 Full-bridge isolated DC-DC converter with a two-cell diode-capacitor network that is ZCS resonant at high step-up.

The diodes D_{21} and D_{22} are conducting with S_1=S_4=OFF and S_2=S_3=ON prior to the t_0 instant in mode 1 (t_0-t_1).

The resonant inductor current and the boost inductor current, i_{L_k} =-i_L, are identical. The voltages at the drain sources, v_{s1} and v_{s4}, fall to zero as soon as S_1 and S_4 are turned on at time t_0. It is being conducted by D_{21}, D_{22}, S_1, S_2, S_3 and S_4. The resonant circuit is composed of L_m, L_k, and C_r. The voltage of capacitor C_r and C_{21} are coupled ($V_{C_{21}}$). $I_{L_k}$is linearly decreasing as $V_{C_{21}}$ / (nL_k). In contrast to switch S_2, S_3, current through switch S_1, S_4 increases. For this time period, the following time-domain state equations apply:

$$v_{C_r}(t) = -\frac{1}{n} v_{C_{21}} \tag{24}$$

$$i_{L_k}(t) = \frac{v_{C_{21}}}{nL_k}(t - t_0) - i_L \tag{25}$$

$$i_{S_1}(t) = i_{S_4}(t) = \frac{1}{2}\left(i_L - \left(-i_{L_k}(t)\right)\right) = \frac{1}{2}\frac{v_{C_{21}}}{nL_k}(t - t_0) \tag{26}$$

$$i_{S_2}(t) = i_{S_3}(t) = \frac{1}{2}\left(i_L + \left(-i_{L_k}(t)\right)\right) = i_L - \frac{1}{2}\frac{v_{C_{21}}}{nL_k}(t - t_0) \tag{27}$$

As soon as the leakage inductor current i_{L_k}=0 at t_1 reaches zero, the diodes D_{21} and D_{22} are disabled. (25), from, is the time window for mode 1. (25)

$$T_{10} = t_1 - t_0 = \frac{n i_L L_k}{v_{C_{21}}} \tag{28}$$

Mode 2 (t_1-t_2): At the instant of t_1, the transformer's secondary side's diodes are all shut off. L_k and C_r combine to form a resonant circuit. The initial voltage of C_r is - $V_{C_{21}}$/n. The leakage inductor current I_{L_k} and the capacitor voltage $V_{C_r}$are these:

$$i_{L_k}(t) = \frac{v_{C_{21}}}{nZ_r}\sin\left(\omega_r(t - t_1)\right) \tag{29}$$

$$v_{C_r}(t) = -\frac{v_{C_{21}}}{n}\cos\left(\omega_r(t - t_1)\right) \tag{30}$$

Where: $\omega_r = 1/\sqrt{L_k C_r}$ is the resonant frequency. Z_r(t) = $\sqrt{L_k/C_r}$ is the impedance of resonant network.

Currents in switches i_{s1} and i_{s4} are still increasing, whereas currents in switches i_{s2} and i_{s3} are still decreasing.

$$i_{S_1}(t) = i_{S_4}(t) = \frac{1}{2}(i_L + i_{L_k}(t)) = \frac{1}{2}\left(i_L + \frac{v_{C_{21}}}{nZ_r} sin(\omega_r(t - t_1))\right) \tag{31}$$

$$i_{S_2}(t) = i_{S_3}(t) = \frac{1}{2}(i_L - i_{L_k}(t)) = \frac{1}{2}\left(i_L - \frac{v_{C_{21}}}{nZ_r} sin(\omega_r(t - t_1))\right) \tag{32}$$

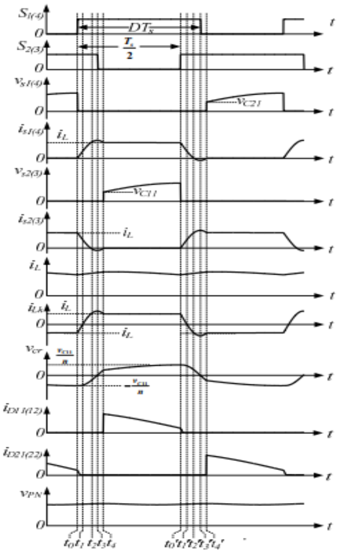


Fig.9 Principle of operation of a two-cell diode-capacitor network in a ZCS resonant high step-up full-bridge isolated DC-DC converter.

The current of switches i_{s2}, i_{s3} decreases to zero at the t_2 instant and increases in the opposite direction in mode 3 (t_2-t_3). The voltage of the resonance capacitor V_{C_r}falls to zero as the maximum resonant inductor current i_{L_k} reaches i_P. Equation allows for the calculation of both the time interval for mode 3 and the maximum resonant inductor current (31).

$$i_P = |i_{L_k}(t)|_{max} = \frac{v_{C_{21}}}{nZ_r} \tag{34}$$

$$T_{32} = t_3 - t_2 = \frac{\pi/_2 - \omega_r T_{21}}{\omega_r} \tag{35}$$

Mode 4 (t_3-t_4): Resonant capacitor voltage V_{C_r} and resonant inductor current iLk start to rise and fall, respectively, at time instant t_3. By the fourth instant, the current i_{L_k} has equaled i_L. Current commutation is complete and S_2 and S_3 no longer have their freewheeling diodes on. S_2 and S_3 must be disabled between time steps 2 and 4 in order to achieve ZCS. According to Fig.9, during a switching time period, the duration of the second half of the resonant period should be a little bit longer than the interval between power switch on states.

$$\frac{1}{2}T_r \geq (D - 0.5)T_s \tag{36}$$

After the t_4 instant, when S_1 and S_4 are turned on and S_2 and S_3 are turned off, the resonant capacitor C_r is charged by a DC source connected in series with a boost inductor. The diodes D_{11} and D_{12} become conducting and C_{11} and C_{12} clamp the voltage across C_r's resonant capacitor. ($v_{C_r} = n_0/n_1 v_{C_{11}} = n_0/n_1 v_{C_{11}}$).

After t_4 instant, when S_1=S_4=ON, S_2=S_3=OFF, the resonant capacitor C_r is charged by a DC source connected in series with a boost inductor.

III. PI CONTROLLER

A closed-loop Proportional-Integral (PI) controller is a control system that uses feedback to maintain a desired level of output from a process or system. It is a type of feedback controller that calculates an error signal by comparing the actual output of the system with the desired output, and then adjusts the control input to minimize the error. The integral term helps to eliminate steady-state errors in the system. A PI controller uses a set of proportional and integral gains to determine the amount of control input needed to adjust the system output to the desired level. These gains are usually adjusted through a process called tuning, which involves measuring the system response to different control inputs and adjusting the gains to achieve optimal performance. In this project in order to generate the pulses to the DC-DC Converter PI based controlling topology is implemented.

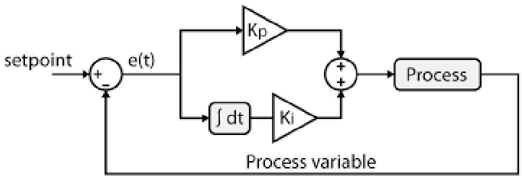


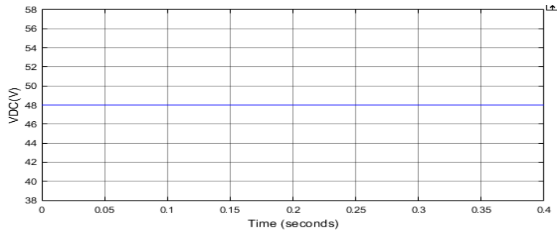
Figure 10: Proposed PI Controller

The above fig.10 depicts the internal structure of PI controller.

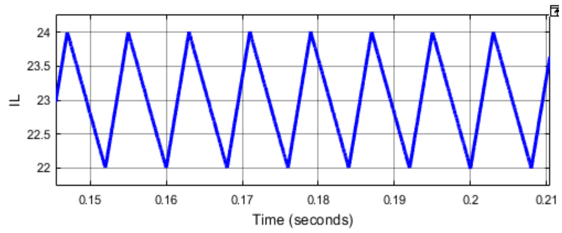
IV. RESULTS AND DISCUSSION:

Numerical simulations using MATLAB/Simulink have been conducted to verify the theoretical analysis and operating principles. To give capacity to the associated loads, a DC source is incorporated. For the ordinary open-circle framework and the shut circle PI-based framework, utilizing the high move forward DC converter and ZCS thunderous circuit, separately, reproduction results are introduced.

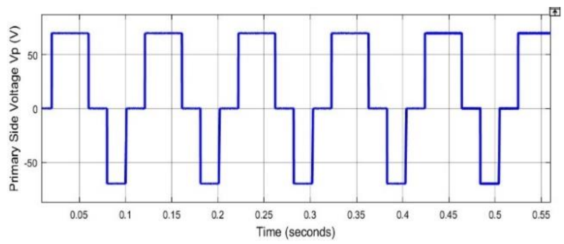
Case-1 Simulation results related to high step-up full-bridge DC-DC converter with multi-cell diode-capacitor network at d_{son} =0.65 conventional and proposed system



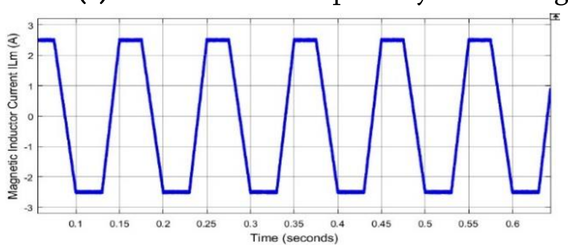
(a) DC link Voltage V_{dc}



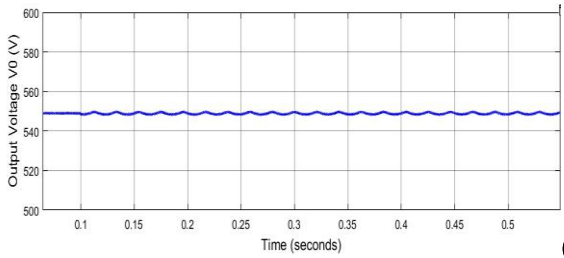
(b) Boost inductor current i_L.



(c) The transformer primary side voltage V_p

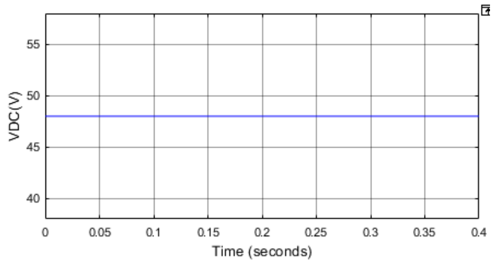


(d) The Transformer magnetic inductor current i_{L_k}

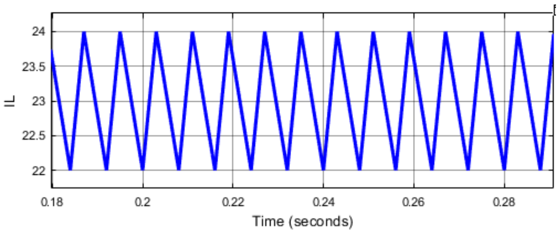


(e) Output voltage V_o

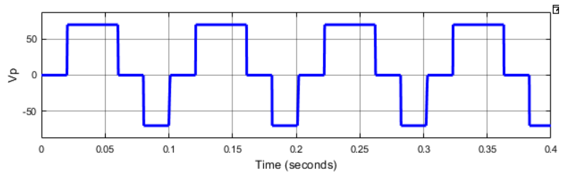
Fig.12 Waveforms of high step-up full-bridge DC-DC converter at d_{son} =0.65 with open loop topology with open loop system



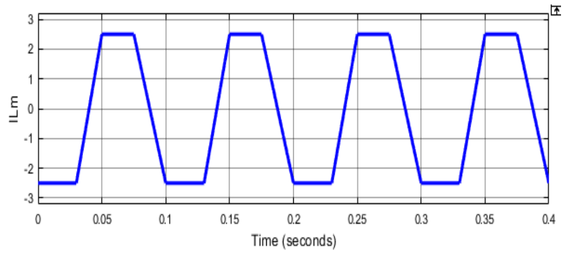
(a) DC link Voltage V_{dc}



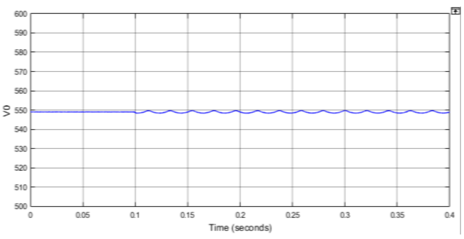
(a) Boost inductor current i_L.



(b) The transformer primary side voltage V_p



(d)The Transformer magnetic inductor current i_{L_k}

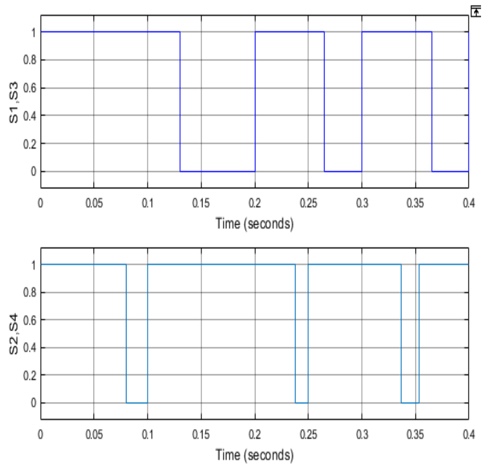


(e)Output voltage V_o

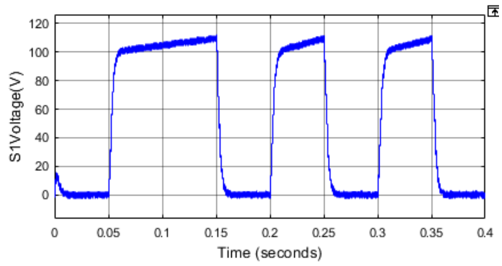
Fig.13 Waveforms of high step-up full-bridge DC-DC converter with multi-cell diode-capacitor network (d_{son} =0.65) with PI Controller

The previously mentioned figure shows the consequences of the reproduction for both open circle and shut circle frameworks. While the accompanying circumstances are met: V_{dc}=48, Vo=540 , n=2, and R_{Load}=300, Figure 13 shows the waveforms of a confined high move forward full scaffold DC converter with a two-cell diode-capacitor organization (N=2). The waveforms comprise of the essential side voltage V_P, yield voltage V_O, support inductor current i_L, spillage inductor current Kind, among others. The obligation proportion is 0.65 in a harmony state. Contrasting the two control geographies makes clearly the proposed PI geography diminishes waveform spikes.

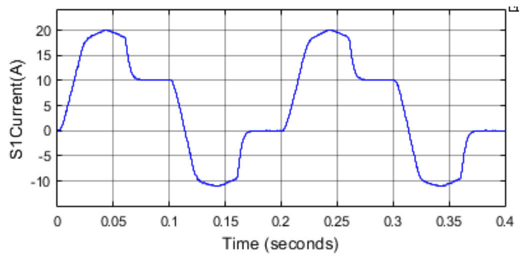
Case-2 Simulation results related to ZCS resonant circuit with conventional and proposed system



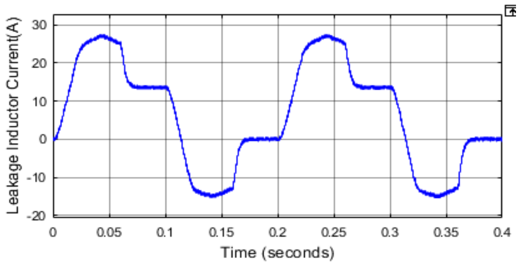
(a) Drive signal



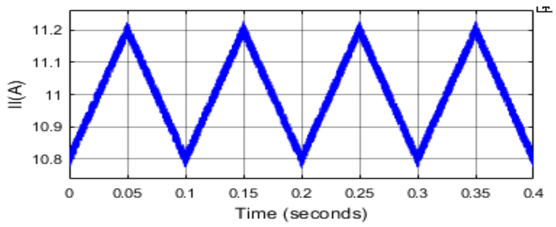
(b) Switch Voltage(V)



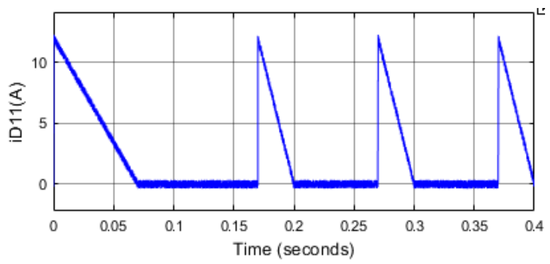
(c) Switch Current(A)



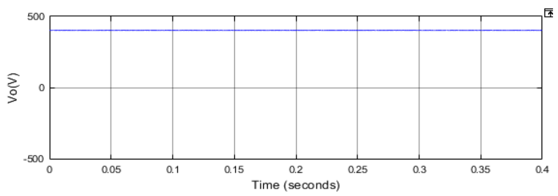
(d) Leakage Inductor Current i_{L_k}



(e) Boost Inductor Current i_L

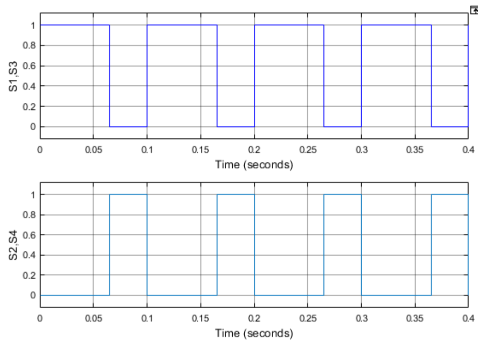


(f) Diode Current

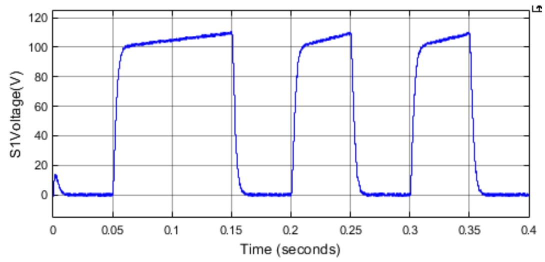


(g) Output Voltage V_o

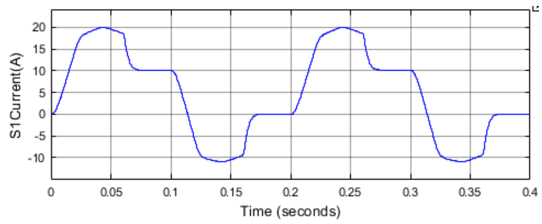
Fig.14 Waveforms of ZCS resonant high step-up full-bridge isolated DC-DC converter with two-cell diode-capacitor network in open loop controlling topology



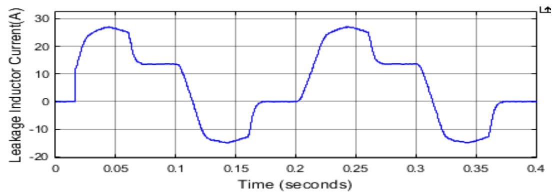
(a) Drive signal



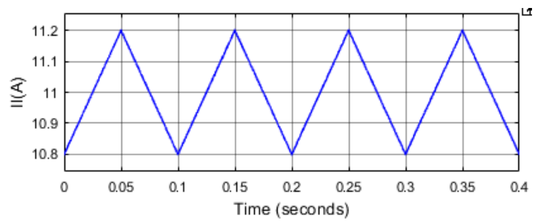
(b) Switch Voltage(V)



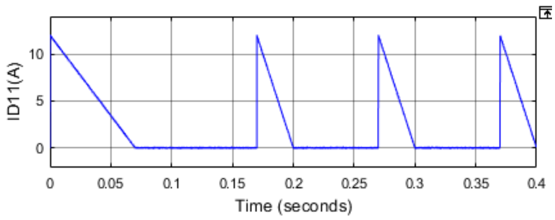
(c) Switch Current(A)



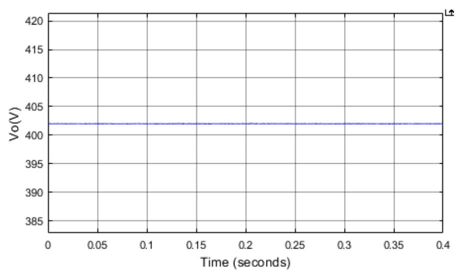
(d) Leakage Inductor Current i_{L_k}



(e) Boost Inductor Current i_L



(f) Diode Current



(g) Output Voltage V_o

Fig.15 Waveforms of ZCS resonant high step-up full-bridge isolated DC-DC converter with two-cell diode-capacitor network with closed loop PI system

It is found that there is an ideal understanding between the deliberate voltage gain and voltage stress from the power devices and the hypothetical qualities. The separated full bridge ZCS resounding high move forward DC converter's waveforms are portrayed in Fig.14. As displayed in the figure, the ongoing moving through the MOSFET is seen to be negative not long before it switches off. By utilizing a PI regulator to deliver the beats for the DC converter, this issue can be tackled. The recommended geography further develops the framework's power quality by bringing down THDs.

V. CONCLUSION

The full bridge boost DC-DC converter achieves high voltage gain by setting the turns ratio of high-frequency transformer. Conventional boost derived converters with multi-cell diode-capacitor network have inrush current issue. In order to overcome these drawbacks, this paper proposes a implementation of zero current switching for high step-up full-bridge isolated DC-DC converter with multi-cell diode-capacitor network which exploits the features and advantages of multi-winding transformer and diode-capacitor network. It avoids inrush current issue and achieves almost zero output voltage ripples Furthermore, it can use the leakage inductor of transformer and resonant capacitor to achieve ZCS, which is beneficial to increase efficiency. A closed-circuit PI regulator-based high-movement DC converter project can be planned and implemented and has evaluated for the better results when compared to the conventional system.

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Cite this article as :

Dr. V. Anil Kumar, Dr. G. Madhusudhana Rao, B. Lalitha Kiranmai, S. Nikhilesh, P. Lakshmi Saroja, P. Venkata Divyasudha, "Implementation of Zero Current Switching for High Step-Up Full Bridge Isolated DC-DC Converter with Multi-Cell Diode Capacitor Network", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 10 Issue 2, pp. 687-696, March-April 2023.

Journal URL : https://ijsrst.com/IJSRST523102100