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Design and Analysis of Hybrid Converter for High Voltage Medical Applications

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ABSTRACT

In recent days there is need for high voltage from the renewable energy sources and the renewable energy is harvested in low voltage levels to solve the issues the paper proposes a hybrid converter for boosting high voltage with less ripples and low current. The proposed converter is proved to be much efficient then the individual DC-DC converter and can withstand the changes in the input voltage from the renewable sources such as photovoltaic panels and fuel cells. The results of the proposed converter are compared with the conventional DC-DC converters in the terms of output voltage and the output current. The result indicating that the proposed converter is efficient with higher output voltage and low current which is suitable for medical applications.

KEYWORDS: *Hybrid converter, photovoltaic voltage (PV), conventional converters.*

I. INTRODUCTION

In the day to advancing world the need for high voltage in the field of medical science is increasing and to meet the requirement of such applications the proposed converter is found to be suitable. The ultimate application of medical science is to improve to diagnose and cure the health issues accurately. Hybrid converter is used for producing constant output voltage since the renewable is found to be varying depending upon the input variation in the climatic conditions [1]. The bi fly back model is proved to be effective with soft switching since it reduces the transformer core loss and reduces the stress in the switch [2]. Another main development in the field of bio-medical is non-lethal and non-ionising ultrasonic waves for diagnosing and examining of the human body [3]. In the laser surgery the bi-polar high voltage pulses are used these are generated from the solid-state generators in the Marx generators [4]. In the fly-back converter the high voltage transmission causes the voltage spikes in the transformer winding in can affect the input voltage in the primary circuit which is compensated by the addition of fly-back snubber [5]. The prominent features of the proposed drivers are the capacitive isolation feature, inherent low line current distortion, and high-power factor [6]. The HVLP fly-back converter is used for achieving steady state high voltage with the help of parasitic capacitances to secondary side of the fly-back transformer [7]. X-ray diagnostic tube requires the voltage level of 150KV to operate the propose a novel interleaved converter with ISABC and CISABC model for higher voltage gain [8]. The paper proposes an interleaved structure for high voltage with planar transformer for multiple output sources with LC-LC converter [9]. The high voltage high frequency voltage can be achieved by the use of GaN based switch for soft switching operation and higher switching speed [10]. The Fly-back circuit works in discontinuous conduction mode (DCM) to realize the power factor correction (PFC) function, and the Class-E circuit is used as DC-DC converter to transform the energy to the LED load. The integrated topology can decrease the cost of system. Moreover, the Class-E converter provides soft switching operation in resonant mode, which can improve the converter efficiency [13]. A high efficiency step-up and step- down converter for conversion it uses a clamp capacitor as an active capacitor and energy is stored in the leakage inductances is recycled [14]. It uses an active clamp fly-back to achieve a soft switching at high switching frequency and high power and secondary side is provide with a resonance to achieve reduced rms current in the primary side to improve the efficiency [15].

II. NEED FOR HYBRID CONVERTER

Since both the converters have some drawbacks individually, we can mitigate these drawbacks by merging these two converters effectively in the way they componentizing each other. Boost converter has the drawbacks such as high EMI from the large output capacitors, it cannot maintain a higher efficiency at duty cycle above 60%, so that cannot be used for high voltage applications, there is no isolation between the input and output sides. Similarly, the fly-back has the following drawbacks such as more EMI and leakage reactance because of the huge air gap, ripple current is high, higher core losses because of huge inductance and large capacitance at the output side. The above-mentioned drawbacks in both converters can compensated by merging both the converters in a way that it doesn't affect the individual performance of parental converters.

III. CIRCUIT CONFIGURATION AND WORKING

The proposed converter is merge of conventional converter such as boost converter and bi fly-back converter by using the advantages of both the parental converters. The boost converter has the ability to operate at the medium and high voltage applications and fly-back can operate in the OFF condition so that the output voltage gain is high. a hybrid step-up converter can be designed by combining the advantages of both converters for a wide input range operation. There are different varieties of converters are available other than this two, though by considering various parameters like the number of components, compactness, transfer efficiency, voltage stress over switch and gain factor, these two are the best options for designing a hybrid converter in this context. While designing a hybrid converter, various challenges have to be considered. While integrating one converter with another, there should not be a performance conflict between the converters. Simultaneously, the individuality should be maintained as well as the disadvantages should be mitigated. In the proposed topology the bi fly-back is used which reduces the transformer voltage spikes in the primary voltage side and improve the quality of the input voltage in the transformer. The proposed converter consists of one switch S1, three diodes (D1, D2, D3), two capacitor (C1 & C2) and resistive load. The proposed converter can operate in two modes of operation based on the switch status.

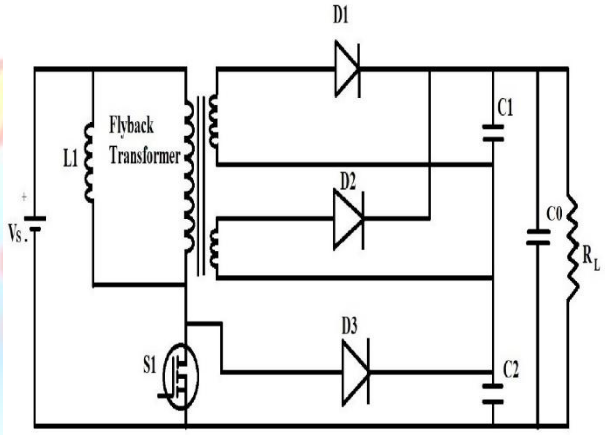

Fig. 1 Circuit diagram of proposed converter

MODE 1:

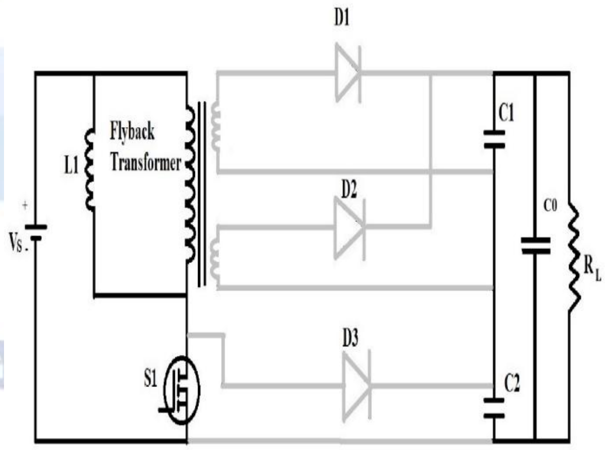

Fig. 2 Mode 1 operation

In mode 1 operation, the switch s1 is turned ON so the primary side of the fly-back transformer is charged along with the inductor from the DC voltage sources. The output capacitor will provide power to the load un-interrupted by the energy stored from the previous operations. The current will flow from the supply voltage and charges the inductor L1 and the primary winding of the fly-back transformer. The magnitude of the current in the primary winding is given by I_P^2,

The input voltage is given by,

$$V_{in} = L_{pri} * \frac{d}{dt} i_{pri} \qquad (1)$$

During the ON state, the inductor current is given by,

$$\frac{d}{dt} I_L = \frac{v_{in}}{L} \qquad (2)$$

At the end of the ON state the inductor current is given by,

$$I_{L(on)} = \frac{d}{dt}\left(\frac{I_p^2}{2L}\right) V_{in} \qquad (3)$$

Where I_(p)is the magnitude of the current in the inductor

The voltage drop on the diode is given by,

$$V_{diode} = V_o + E_{dc} * \frac{N_2}{N_1} \qquad (4)$$

MODE 2:

In mode 2, the energy stored in the primary inductance of the fly-back transformer is transferred into the secondary winding during the off condition. The energy stored from the secondary windings ofthe fly-back transformer is transferred to the output capacitances C0 through the diodes(D1&D2). The inductor L1 discharges the stored energy via of capacitor C2 thus transferred to the load side.

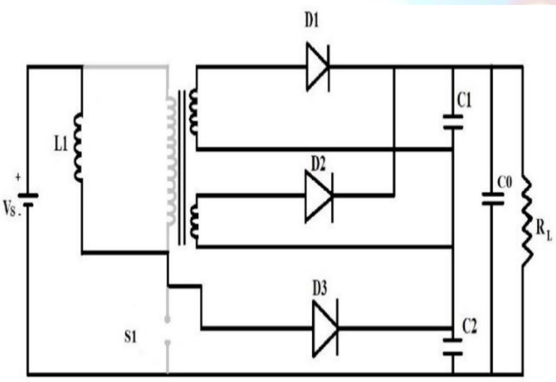

Fig. 3 Mode 2 operation

During the OFF state, the inductor current is given by,

$$\frac{d}{dt} I_{L(off)} = \frac{(-V_o(V_{in} - V_o)(1-D)T)}{L_{sec}} \qquad (5)$$

The output power can be expressed by the equation,

$$P_o = \frac{1}{2} L I_p^2 F_{switch} \qquad (6)$$

The total inductor is given by $I_L = I_{on} + I_{off}$

The output voltage V_o can be given by,

$$V_o = -\frac{N_2}{N_1} . V_{in}\left(\frac{1+D}{1-D}\right) \qquad (7)$$

The voltage stress in the switch is given by,

$$V_{out} = -\frac{N_2}{N_1} . \frac{D}{1-D} . V_{in} \qquad (8)$$

IV. SIMULATION DIAGRAM AND DESIGN PARAMETERS

The simulation of the proposed converter is carried out in the MATLAB simulation with parameter based on the individuality of the parental converters. The simulation and design parameters of the proposed hybrid converter is discussed below.

Design of the fly-back transformer involves the following parameters.

$$V_L = NBA$$

$$V_{min}\left(\frac{1}{2F}\right) = NB_{max}\, A$$

$$N_{min} = \frac{V_{max}}{2fAB_{max}}$$

N_{min}, *is the minimum number of turns to avoid transformer saturation*

Turns ratio $\frac{N_s}{N_p} = 2\frac{V_{out}}{V_{in}}$

The following formulas are used for the design of the proposed hybrid converter

Storage inductance $L_1 = \frac{D(1-D)^2 R_L}{2F}$

Capacitances $C_1 \& C_2 = \frac{(1-D)}{f * R_L * Ripple\ \%}$

Output capacitance=$C_0 = \frac{I_{out\ (m)} * D}{f_s * \Delta V_{out}}$

Load resistance $L_R = \frac{Total\ \ voltage\ \ of\ converter}{Total\ \ current\ \ of\ converter}$

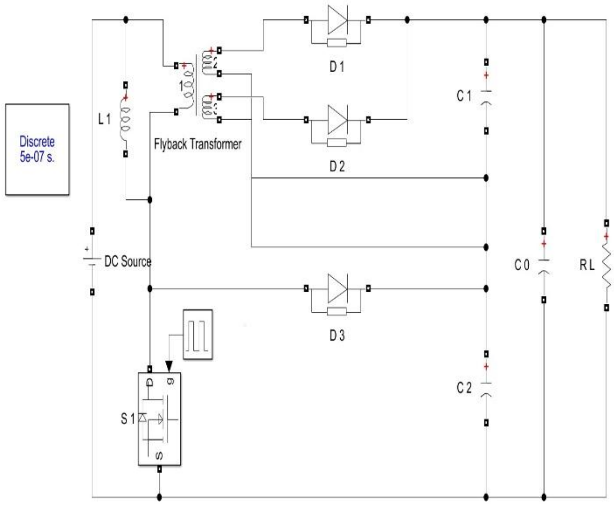

Fig. 4 Simulation Diagram of proposed converter

TABLE 1: Specification of The Proposed Converter

S.NO	PARAMETERS	VALUES
1	Input Voltage	24V
2	Output Voltage	128V
3	Switching Frequency	100KHZ
4	Duty cycle	70%
5	Inductance L1	50mH
6	Capacitor C1&C2	22µF
7	Output capacitance C0	300 µF
8	Load Resistance RL	145Ω

V.SIMULATION RESULTS AND DISCUSSION

The following session contains the results and the comparison of the proposed converter with other conventional converters and results are discussed. The proposed converter has 5 times more voltage gain then the other conventional converters.

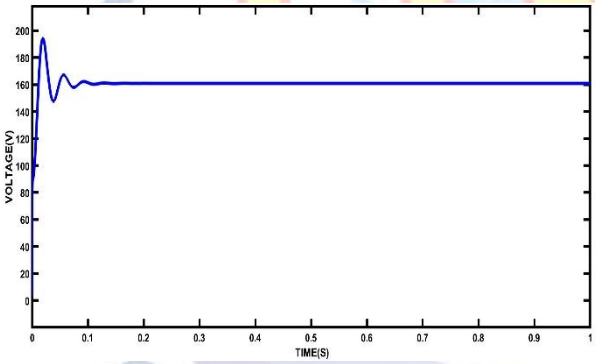

Fig. 5 Output Voltages

The figure 5 shows the output voltage of the proposed converter across the load resistances.

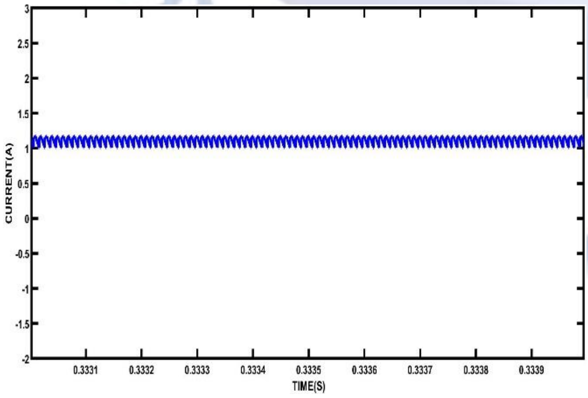

Fig. 6 Output current

The figure 6 represents the load current of the proposed converter.

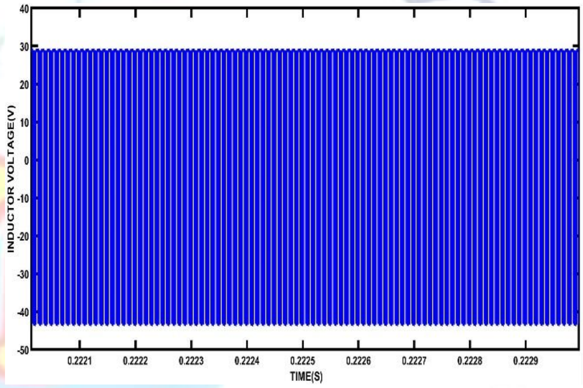

Fig. 7 Inductor Voltages

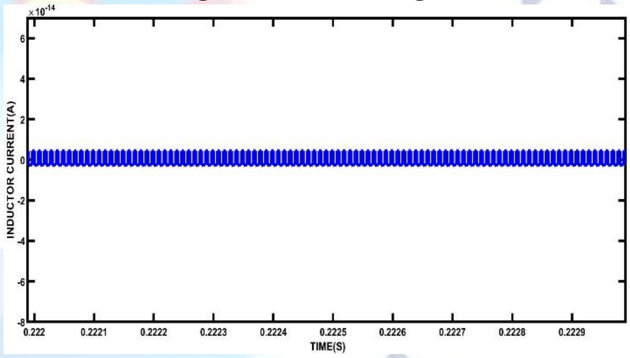

Fig. 8 Inductor Current

The figure 7&8 represents the Inductor voltage and current of the proposed converter.

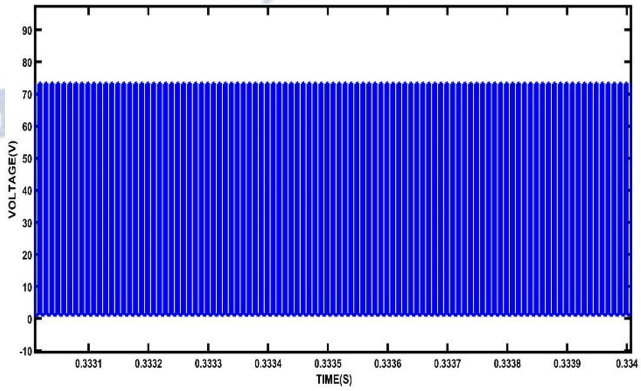

Fig. 9 Voltage stress on the Switch S1

The figure 9 represents the voltage stress across the switch S1 in the proposed converter.

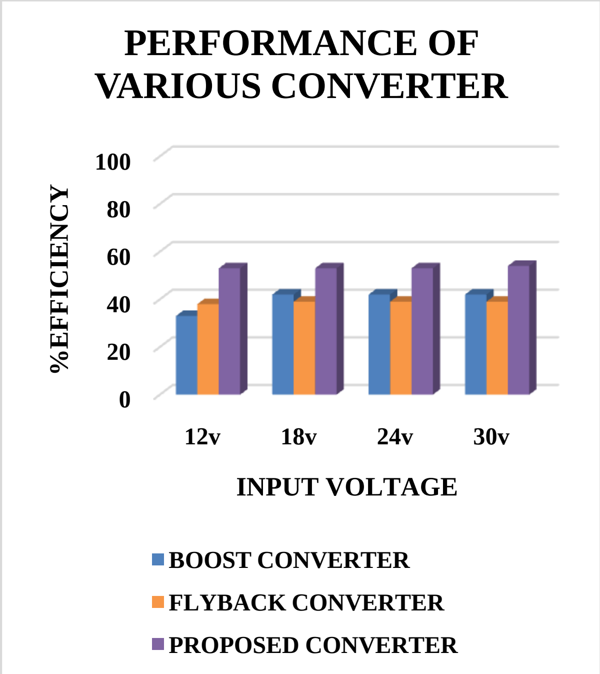

Fig. 10 Performance of proposed converter

VI. CONCLUSION

The paper proposes a hybrid converter for high voltage application. The normal drawbacks in the conventional converter like boost and fly-back converter is overcome by the proposed converter. The losses such as transformer core loss, switching frequency losses are reduced. The converter is proved to be have high gain than the parental converter and maintain their individuality to rectify their own disabilities. Hybrid converter reaches the 5 times gain level with reduced voltage distortion. The results for various input voltages are compared with other conventional converters and displayed. The proposed converter is proved to be much more robust than the conventional converters.

REFERENCES

[1] Peter K. Joseph1, Elan Govan Devaraj 'Design of hybrid forward boost converter for renewable energy powered electric vehicle charging applications' IET Power Electron., 2019, Vol. 12 Issue. 8, pp. 2015-2021.

[2] B.-R. Lin, H.-K. Chiang and C.-Y. Cheng 'Soft-switching converter based on bi-fly back topology' Electronics Letters 9th October 2008 Vol. 44 No. 21.

[3] Yen-chung Huang, kuo-Tso Chen, Kuan-Yi Lu, Jian-chiunLiou and Guo-Zua Wu 'A High-speed High-Voltage Bipolar Pulsar for Medical Ultrasonic Imaging Applications' 2018 IEEE International Conference on Consumer Electronics-Taiwan (ICCE-TW).

[4] L.M.Redondo, Senior Member, IEEE, M. Zahyka, and A.Kandratsyeu 'Solid-State Generation of High-Frequency Burst of Bipolar Pulses for Medical Applications' IEEE Transactions On Plasma Science, VOL. 47, NO. 8, August 2019.

[5] T.-F. Wu, Y.-C. Chen, J.-G. Yang, Y.-C. Huang, S.-S. Shyu* and C.-L. Lee '1.5 kW Isolated Bi-directional DC-DC Converter with a Fly-back Snubber' PEDS 2009: 8th International Conference on Power Electronics and Drive systems.

[6] D. Shmilovitz, Member, IEEE, A. Abramovitz, Member, IEEE, and I. Reichman 'A Family of Bridgeless Quasi-Resonant LED Drivers' IEEE Transactions on Power Electronics, VOL. 31, NO. 3, March 2016.

[7] Vaishnavi Ravi and N Lakshminarasamma Modelling, 'Analysis and Implementation of High Voltage Low Power Fly-back Converter Feeding Resistive Loads' 10.1109/TIA.2018.2838547, IEEE Transactions on Industry Applications.

[8] Michael Leibl, Johann W. Kolar, and Josef Deuringer 'High Bandwidth Non-Resonant High Voltage Generator for X-Ray Systems' Cpss Transactions on Power Electronics and Applications, VOL. 3, NO. 2, JUNE 2018.

[9] Bin Zhao, Member, IEEE, Ziwei Ouyang, Senior Member, IEEE, Maeve Duffy, Senior Member, IEEE, Michael A. E. Andersen, Senior Member, IEEE and Gerard Hurley, Fellow, IEEE 'An Improved Partially Interleaved Transformer Structure for High-voltage High-frequency Multiple-output' DOI 10.1109/TIE.2018.2840499, IEEE Transactions on Industrial Electronics.

[10] Shanshan Gao, Student Member, IEEE, Yijie Wang, Senior Member, IEEE, Yueshi Guan, Student Member, IEEE, and Dianguo Xu, Fellow, IEEE 'A High-Frequency High Voltage Gain DCM Coupled-Inductor Boost LED Driver Based on Planar Component' IEEE Transactions on Industry Applications, VOL. 55, NO. 5, September/October 2019.

[11] Moumita Das, Student Member, IEEE and Vivek Agarwal, Fellow, IEEE 'Design and Analysis of a High Efficiency DCDC Converter with Soft Switching Capability for Renewable Energy Applications Requiring High Voltage Gain' IEEE Transactions on Industrial Electronics 2019.

[12] Dr. Shreelakshmi M, Dr. Moumita Das and Dr. Vivek Agarwal 'Design and Development of a Novel High Voltage Gain, High Efficiency Bi-directional DC-DC Converter for Storage Interface' DOI 10.1109/TIE.2018.2860539, IEEE Transactions on Industrial Electronics.

[13] Shu Zhang ,YupingQiu ,Yijie Wang ,Xiaosheng Liu ,J. Marcos Alonso,Dianguo Xu 'A high-power-factor integrated-stage AC-DC LED driver based on flyback-class E converter', 2017 IEEE Industry Applications Society Annual Meeting.

[14] Kuo-Ching Tseng ,Shih-Yi Chang ,Chun-An Cheng 'Novel Isolated Bidirectional Interleaved Converter for Renewable Energy Applications', IEEE Transactions on Industrial Electronics (Volume: 66 , Issue: 12 , Dec. 2019).

[15] LingxiaoXue ,Jason Zhang 'Highly Efficient Secondary-Resonant Active Clamp Fly-back Converter', IEEE Transactions on Industrial Electronics (Volume: 65 , Issue: 2 , Feb. 2018).