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Current Fed Isolated Dual Half Bridge Converter With Low Input Current Ripple and Improved Efficiency

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Abstract: A high step-up current-fed resonant converter is required for interfacing the sustainable power sources, such as PV panels and fuel cells, which are characterized by low-voltage high-current output and have strict current ripple requirement. A DC DC resonant converter with intermediate AC link provides higher gain with soft switching abilities. LCC resonant converters provide high voltage gain with better transformer utilization. But due to the presence of resonance, there will be circulating energy which is carried by the split capacitors. This circulating energy will increase input current ripple, conduction losses. Considering the necessity of high voltage boosting function with low input current ripple and low circulating energy, the most appropriate converters are current fed full bridge or push-pull converter with output voltage doublers. Since the converter efficiency can be considerably improved by reducing the count of the primary switches and implementing a transformer of a simple structure, a double inductor push-pull converter was selected. The resonant tank absorbs self-winding capacitances of transformer and junction capacitances of rectifying diode into the resonant capacitor. Thus current spikes get suppressed within the resonant circuit. In order to further improve the efficiency, voltage double circuit is applied to the output rectifier, respectively. This proposed system will reduce the circulating energy, since double inductor push-pull converter will act as an isolated double boost converter. This system is proposed with an expectation of improved efficiency, low input current ripple and low circulating current. A simulation of the proposed system is modeled with input voltage of 30V and output voltage of 380V is realized in MATLAB/Simulink. The system guarantees high voltage gain and efficiency.

Keywords: Resonant Converter, Front End Converter, Voltage Doubler

I. INTRODUCTION

The fossil fuel related environmental issues and the challenges to sustainable industrialization stimulate the development of distributed generation based on renewable energy. Some of the renewable power sources, such as PV panels and fuel cells, are characterized by low-voltage current output and have strict current ripple requirements. Consequently, a dc–dc converter with high step-up capability, galvanic isolation, low input current ripple, and high efficiency is required. Current-fed converters attract more and more interests in such kind of applications, with their inherent properties of high boost capability and small input current ripple. Thus, the transformer's turns ratio can be reduced, and the bulk input filters can be shrunk as compared with the conventional voltage fed converters. However, the current-fed pulse width modulated converters still have the problems of high voltage and current spikes resulting from the leakage inductance and winding capacitance of the transformer, and high voltage stress on the rectifying diodes due to their reverse recovery. Hence, their operating frequency should be low, and the power conversion efficiency is also limited.

Resonant techniques promise high-efficiency power conversion while operating at high switching frequency with their instinctive capability of well utilizing the circuit parasitics and achieving Zero-Voltage Switching (ZVS) or Zero-Current Switching (ZCS) for the active switches. Moreover, the current fed parallel resonant converters also have high step-up feature, driven by a square wave current source. With such techniques, not only the parasitics of the transformer can be utilized, but also the turns ratio can be further reduced. Most of the efforts for the current fed resonant converters were focused on achieving ZVS of the primary switches.

However, in low-voltage high-current input applications, ZVS is not that much important, while ZCS is the key for switching loss elimination, whereas the existing leakage inductance of the transformer still causes high voltage spikes

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on the switches. To achieve high voltage gain and better performance, many single- switch high step-up converters using the switched capacitor topology, switched inductor topology, voltage lift technique, coupled inductor, and hybrid methods have been proposed. The drawbacks of these topologies are, they have high input current ripples. Considering the necessity of high voltage boosting function with low input current ripple and low circulating energy, the most appropriate converters are current fed full bridge or push-pull converter with output voltage double. Since the converter efficiency can be considerably improved by reducing the count of the primary switches and implementing a transformer of a simple structure, a double inductor push-pull converter was selected. To avoid this problem, dual inductor step- up converters with the voltage-double module topology have been proposed.

The high step up converter topology proposed in this paper uses an dual inductor converter with a voltage double module. The secondary sides of the inductors in the converter are in interleaved series connection and shared by two voltage-double modules to establish the interleaved energy storage. The proposed converter consists of a square wave current source generator, a resonant tank, and an output voltage doubler. The current fed half-bridge structure is adopted as the square wave current source generator, with its inherent merits of low input current ripple, low primary current of the transformer, high step-up capability, and common ground gate driving. The resonant tank offers high voltage gain to reduce the turns ratio of the transformer. Meanwhile, it absorbs both the self-winding capacitances of the transformer and the junction capacitances of the rectifying diodes into its resonant capacitor; thus, the current spikes within the circuit are well suppressed.

By operating the two primary switches with overlapped conduction time, a resonance between the leakage inductance and the resonant capacitor is introduced during the overlapping interval to achieve soft commutation of the primary current which finally flows through the anti-parallel diode before the switch turning off. Thereby, the primary switches are turned off with ZCS, and the voltage spikes across the switches are reduced.

The capacitor output filter clamps the peak voltage of the resonant capacitor to the output voltage during the conduction period of the rectifying diodes, whereas during the non-conduction period, the voltage of the resonant capacitor could resonate down. In this way, the circulating energy within the resonant tank and the related conduction losses are reduced, the overshooting of the primary current is limited, and ZCS is achieved for the rectifying diodes without any additional efforts in full load range. For efficiency improvement, a voltage doubler was finally selected instead of the bridge rectifier.

II. PROPOSED SYSTEM

The proposed system is composed of the DC voltage source, the DC–AC front end inverter, soft switching elements, transformer, the AC–DC rectifier, capacitor filter and the load. Since the output of solar is a very low voltage. In order to convert this low voltage DC to a high voltage DC, a DC-DC converter with intermediate AC links provides higher gains.

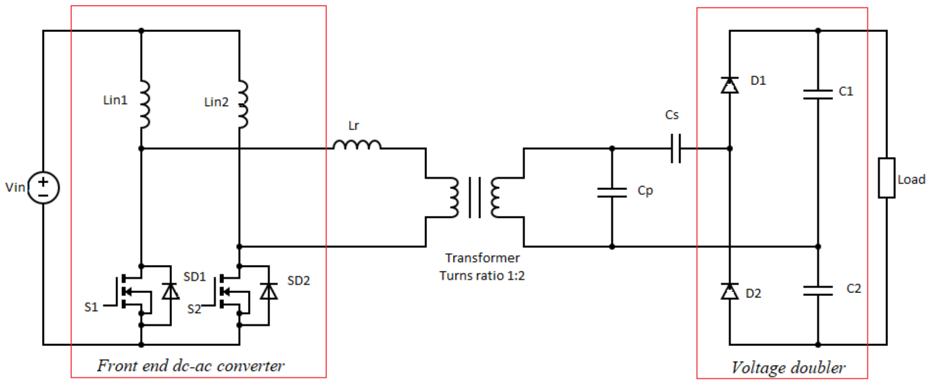

Fig. 1: Proposed system

The proposed system consists of two parts, a front end DC-AC converter and a voltage doubler as shown in fig. 1. The front end DC-AC converter employs current-fed half bridge structure which includes two input inductors Lin1 and Lin2 and two active switches S1and S2. DS1and DS2 are the anti-parallel diodes of S1 and S2, respectively. The resonant tank consists of a resonant inductor Lr which participates in the resonance together with resonant capacitor Cs and Cp only during the commutation period of the primary current ipri. The transformer's leakage inductance and self-winding capacitance are incorporated into Lr and Cp, respectively. Soft switching in front end inverter is obtained through resonance created by Lr and Cp. Voltage doubler at the output stage offers rectification of ac voltage with soft switching of diodes along with voltage doubling characteristic. Since this is a step up converter, double the voltage gain is advantageous for current application. Also soft switching of diodes eliminate the need of snubbers on diodes, ringing of diodes at turn off, need of fast recovery diodes.

Voltage doubler circuit consists of two rectifying diodes D1 and D2 with two output capacitors C1 and C2.The junction capacitances of the secondary rectifying diodes D1 and D2 are also absorbed into Cp. The output capacitors C1 and C2 are much larger than Cp and can smooth the rectified resonant capacitor voltage vCp. Several assumptions are made for the proposed system. Lin1 and Lin2 , C1,and C2 are sufficiently large so that the input current Iin and the output voltage Vo are constant during one switching cycle. The active switches S1 and S2 and the diodes, including DS1 and DS2, are ideal. The parasitics of all passive components are not considered here.

III. OPERATION OF THE PROPOSED CIRCUIT

The proposed converter works in six operating modes to obtain voltage at the output. At first, S1 is on, S2 is off, Lin1 is charged by the input voltage Vin, and Lin2 transfers its stored energy to the load through D2. vCp is clamped to −Vo/2. The current flowing through D2 (iD2) is equal to the transformer's secondary current isec minus the current flowing through Lp (iLp).

Mode 1: In this mode, S1 keeps on, S2 keeps off, iLp is equal to isec, and iD2 drops to zero. All rectifying diodes are off, the current flowing through Lin2 (iLin2) feeds the resonant tank, and Lr is absorbed into Lin2. Mode 1 ends when S2 is switched on. In mode 1, Lin1 is charged by Vin, and vCp resonates up.

Mode 2: In this mode, both S1 and S2 conduct the current, terminals of transformers are shorted, and all of the rectifying diodes keep on blocking. Lr participates in the resonance with Cp for the commutation of ipri. As ipri oscillating from negative to positive is driven by the initial negative vCp, current flowing through S2 (iS2) increases, while current flowing through S1 (iS1) decreases. When iS1 reaches zero, mode 2 ends. It is critical to select a proper Lr based on the overlap time to ensure that iS1 would drop to zero but with little overshooting, and then, S1 could be turned off in the ZCS condition with minimized circulating energy. During this period, Lin1 and Lin2 are both charged by Vin and vCp keeps on resonating up.

Mode 3: This mode is similar to mode 2, while iS1 goes negative. Mode 3 ends S1 when gets off. In this interval, ipri comes to their peaks, and vCp rises across zero but is lower than Vo/2.

Mode 4: This mode is similar to mode 3 except that the negative iS1 flows through DS1 after S1 is off. When iS1 reaches zero, mode 4 ends. This period is expected to be minimized by properly controlling the turn-off point of S1 to eliminate the conduction loss on DS1.

Mode 5: In this mode, S2 keeps on and DS1 blocks off, while S2 keeps on. Lr is absorbed into Lin1, and the current flowing through Lin1 (iLin1) feeds the resonant tank, while Lin2 is still charged by Vin. Mode 5 ends when vCp touches Vo/2.

Mode 6: In this mode, S1 is off, S2 is on, D1 is forced on, and vCp is clamped to Vo/2. Lin1 transfers its stored energy to the load, while Lin2 is charged by Vin. Lp is charged by Vo/2. The current flowing through DS1 (iD1) is equal to isec minus ics. Mode 6 ends when ics is equal to isec and iD1 drops to zero. Because vCp is clamped to Vo/2 during this energy transferring period which takes up most part of the half switching cycle, the circulating energy within resonant tank is minimized, and the related conduction losses are accordingly reduced. As isec is almost constant during this period, the decreasing slew rate of iD1 is dominated by the well-controlled ics. Hence, ZCS can be ideally achieved for D1, and the reverse recovery issue is well eliminated without any additional efforts.

IV. SIMULATION RESULTS

The proposed system is simulated in MATLAB/SIMULINK. The simulation model is shown in fig. 2.The proposed converter is simulated with an input dc voltage of 30V.The switching frequency can be between 100KHz to 150KHz.Here, it is selected as 128KHz. A 5KΩ resistor is used as the load in the proposed system. As a resistive load is used, the output current follows the output voltage waveform. The front end dc-ac converter consists of two input inductors which are not coupled together. Therefore the current through both inductors, iLin1 and iLin2 is similar but with 1800 phase shift. The waveform representing inductor currents are shown in fig.3. Here the input current (iin) will be sum of the two inductor currents (iLin1 and iLin2).The fig.4 represents the input current waveform. Here, the current ripple of iin is very small (about 8%), and its frequency is twice the switching frequency.

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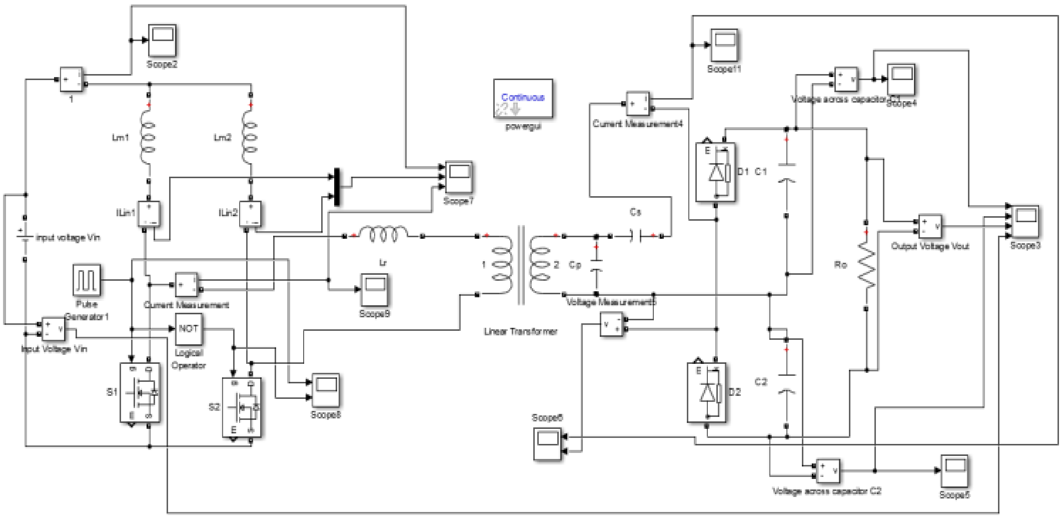

Fig. 2: Simulink model of the proposed system

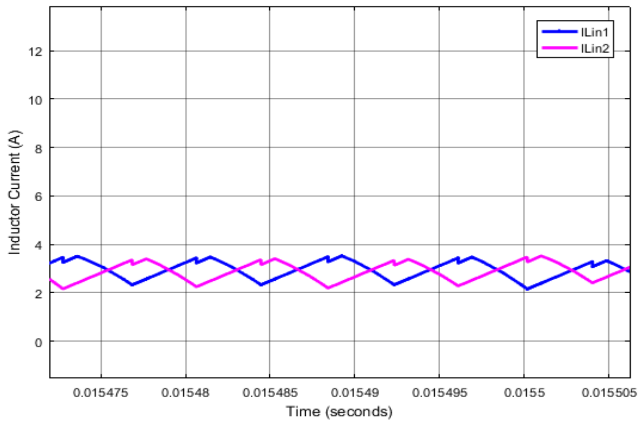

Fig. 3: Inductor currents (iLin1 and iLin2)

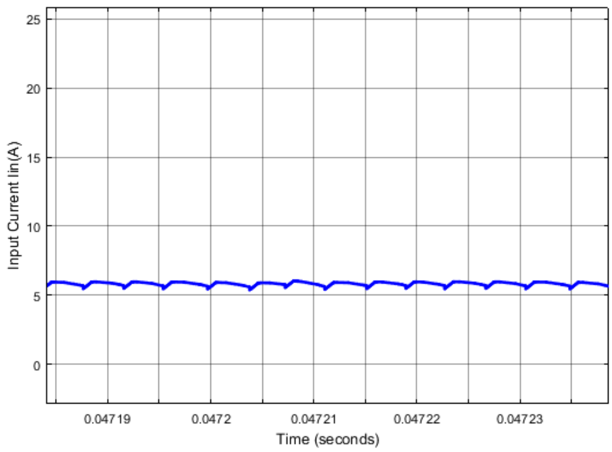

Fig. 4: DC Input current (iin)

Then, a small cost-effective non-polarity cap would be enough to filter the input ripple current. Although two input inductors seem bulky compared to the voltage-fed converters, the proposed converter eliminates the bulky input current ripple filters in which the electrolytic capacitors are always necessary to eliminate it. but have much shorter lifetime compared to the inductors. Hence, the two input inductors will not impact the volume of the whole converter, but they promise a longer lifetime to the converter. Since the input current is relatively high, the two input inductors share the input current, which reduces the primary current of the transformer (ipri). The primary current of the transformer is in

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the square wave shape with spikes as shown in fig.5. The front end dc-ac converter will acts like a square wave current source generator.

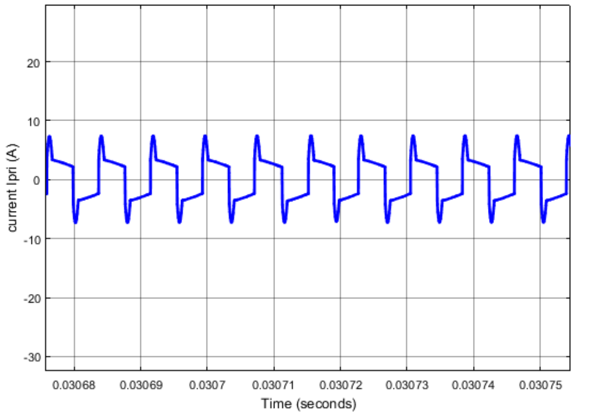

Fig. 5: Transformer primary current (ipri)

The fig.6 shows the voltage across capacitor Cp(vCp). It can be seen that vCp is being equal to half of output voltage (Vo/2). Thus, small circulating energy will be present within the resonant tank. Also voltage across the rectifying diodes D1 and D2, VD1 and VD2 respectively are equal to output voltage Vo without any overshooting. During the positive half cycle diode D1 conducts and D2 will conduct during the negative half cycle diode The fig.7 represents the voltage across diodes D1 and D2.

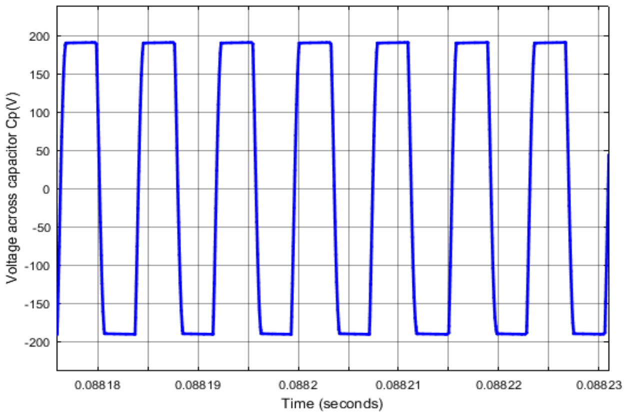

Fig. 6: Voltage across capacitor Cp (vCp)

Current through rectifying diodes, irec will decreases to zero with low slew rate. Thus all the rectifying diodes will operate with ZCS. Therefore, the proposed converter will helps to reduce the circulating current present in the resonant tank. The fig.8 represents current flowing through the rectifying diodes (irec). ZCS operation is also well achieved for all of the rectifying diodes.

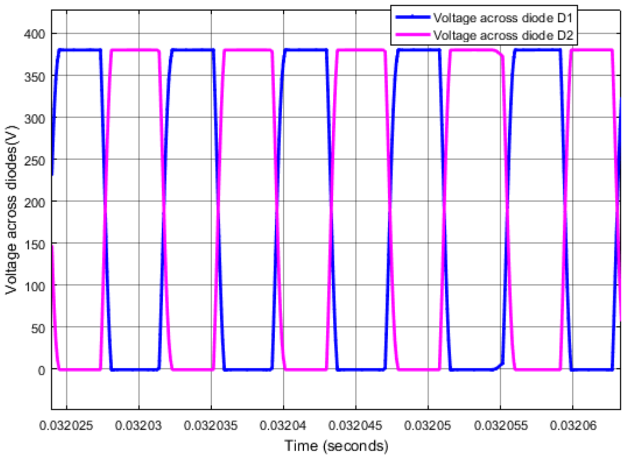

Fig. 7: Voltage across the diodes D1 and D2 (VD1 and VD2)

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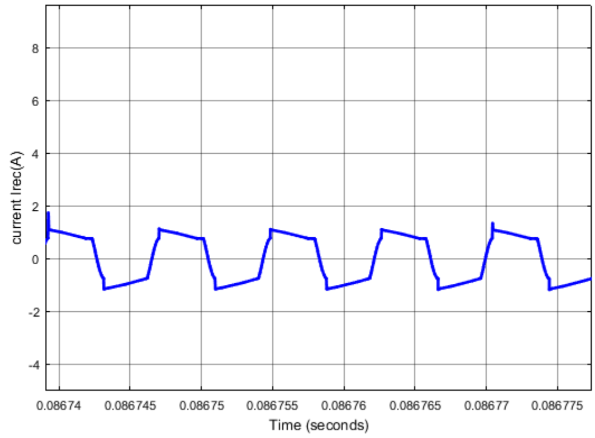

Fig. 8: Current flowing through rectifying diodes (irec)

The voltage doubler circuit provided at the secondary side of the transformer will rectify the output from the transformer and provides a dc output which is double the voltage across the capacitor Cp (vCp). The capacitors C1 and C2 in the voltage doubler circuit will have same rating and it will be charged to same voltage level. The voltage across the capacitors C1 and C2 is shown in fig.9. Here, each capacitor is charged to half of the output voltage or the capacitor voltge is equal to voltage across the capacitor Cp (vCp).

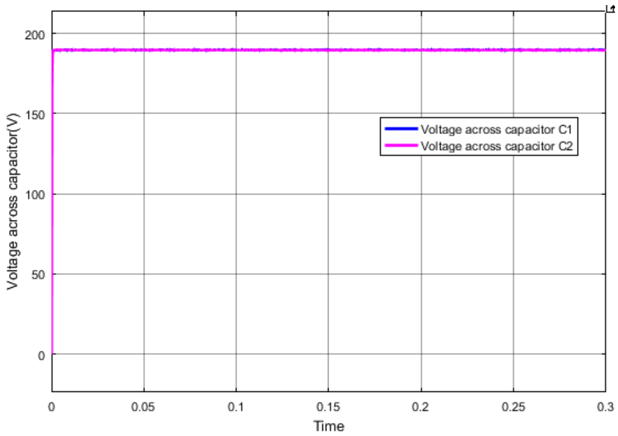

Fig. 9: Voltage across the capacitors C1 and C2

For an input dc voltage of 30V, the proposed converter is designed to provide an output dc voltage of 380V for a load resistor. The output voltage obtained for an input dc voltage of 30V is the double the voltage across the capacitors C1 and C2. That means the gain of the proposed converter is very high. Fig.10 shows the output dc voltage with input dc voltage waveform of dc-dc converter.

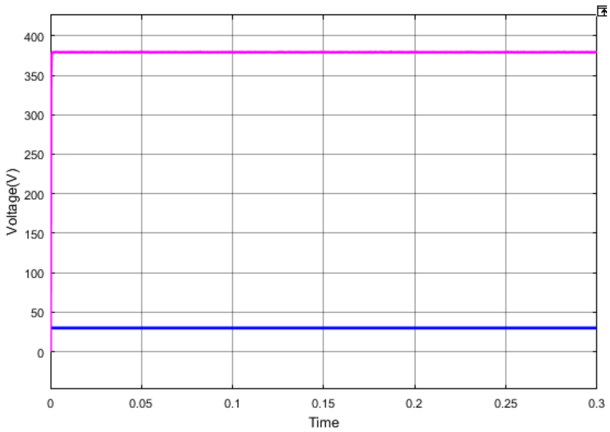

Fig. 10: Output and input dc voltage waveform

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The proposed converter with a dc input voltage of 30V provides 380V dc as output voltage with a reduced input current ripple of about 8%. It resulted as a square wave current source generator with reduced primary current, circulating current. Hence the proposed converter provides higher voltage gain with efficiency more than 90%.

V. CONCLUSION

A current fed isolated dual half bridge converter with low input current ripple and improved efficiency is proposed here. The proposed converter has applications in the area of renewable resources like solar and fuel cells. The operation of the proposed converter is well explained. From the simulation results, it is clear that the current-fed half-bridge structure makes low input current ripple, low primary current for the transformer, high step-up capability. The voltage doubler circuit in the secondary of transformer will raise output voltage to be double of the transformer secondary voltage. Thus proposed converter will provide high voltage gain, and better utilization of the transformer. Also the proposed converter with voltage doubler circuit will help to reduce the circulating energy, limits the overshooting of the primary current of transformer with reduced input current ripple. The proposed converter provides an efficiency about 92% with an output dc voltage of 380V for an input 30V dc.

REFERENCES

[1]. Venkata R Vakacharla, Akshay Kumar Rathore , " Current-fed Isolated LCC-T Resonant Converter with ZCS and Improved Transformer Utilization “in IEEE Transactions on Industrial Electronics ,2018
[2]. M. Forouzesh, Y. P. Siwakoti, S. A. Gorji, F. Blaabjerg and B. Lehman, "Step-Up DC–DC Converters: A Comprehensive Review of VoltageBoosting Techniques, Topologies, and Applications," in IEEE Transactions on Power Electronics, vol. 32, no. 12, pp. 9143-9178
[3]. M. K. Kazimierczuk and R. Cravens, II, "Current source parallel resonant DC/AC inverter with transformer," in Telecommunications Energy Conference, 1994. INTELEC '94., 16th International, 1994, pp. 135-141
[4]. D. Li, B. Liu, B. Yuan, X. Yang, J. Duan and J. Zhai, "A high step-up current fed multi-resonant converter with output voltage doubler," 2011 Twenty-Sixth Annual IEEE Applied Power Electronics Conference and Exposition(APEC),Fort Worth, TX, 2011, pp. 2020-2026
[5]. S Raghu Raman, K W E Cheng, Ye Yuanmao, “Multi-Input Switched Capacitor Multilevel Inverter for High Frequency AC Power Distridution”, IEEE Trans. Power Electronics, Aug. 2017.
[6]. H P Vemuganti, D Sreenivasarao, G S Kumar, A S Spandana, “Reduced Carrier PWM Scheme with Unified Logical Expressions for Reduced Switch Count Multilevel Inverters” IET Power Electronics, vol. 11, no. 5, April 2018
[7]. M. Cacciato, A. Consoli, R. Attanasio, and F. Gennaro, “Soft switching converter with HF transformer for grid-connected photovoltaic systems,” IEEE Trans. Ind. Electron., vol. 57, no. 5, pp. 1678–1686, May 2010.
[8]. S. V. Araujo, R. P. Torrico-Bascope, and G. V. Torrico-Bascope, “Highly efficient high step-up converter for fuel-cell power processing based on three-state commutation cell,” IEEE Trans. Ind. Electron., vol. 57, no. 6, pp. 1987–1997, Jun. 2010.
[9]. C. T. Pan and C. M. Lai, “A high-efficiency high step-up converter with low switch voltage stress for fuel-cell system applications,” IEEE Trans.Ind. Electron., vol. 57, no. 6, pp. 1998–2006, Jun. 2010.
[10]. Wolfs, P.J., "A current-sourced DC-DC converter derived via the duality principle from the half:bridge converter", IEEE Transactions on Industrial Electronics, Vol. 40, No. I, pp. 385-394, Feb. 1993.
[11]. F. Blaabjerg, Z. Chen, and S. Kjaer, "Power electronics as efficient interface in dispersed power generation systems," IEEE Transactions on Power Electronics, vol. 19, pp. 1184 - 1194, Sept 2004

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