Highly Efficient Asymmetrical PWM Full-Bridge Converter for Renewable Energy Sources

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Abstract—This paper provides a particularly green asymmetrical pulse-width modulated (APWM) full-bridge converter for renewable power resources. The proposed converter adopts full-bridge topology and uneven manage scheme to reap the 0-voltage switching (ZVS) turn-on of the strength switches of the primary facet and to lessen the circulating contemporary loss. Furthermore, the resonant circuit composed of the leakage inductance of the transformer and the blocking off capacitor gives the zero-contemporary switching (ZCS) flip-off for the output diode without the assist of any auxiliary circuits. Accordingly, the opposite recuperation trouble of the output diode is removed. Similarly, voltage stresses of the strength switches are clamped to the input voltage. Due to those traits, the proposed converter has the structure to decrease energy losses. Its miles in particular useful to the renewable strength conversion systems. To verify the theoretical analysis and validity of the proposed converter, a 400W prototype is carried out with the input voltage range from 40V to 80V.

Index Terms— full-bridge converter, tender switching, say- metrical PWM

I. INTRODUCTION

With the exhaustion of the worldwide resources and the environmental pollutants, the research at the renewable power sources including gas cells and photovoltaic cells has been regularly extended in business fields [1]-[4]. Generally, the renewable power sources generate low-voltage strength. The photovoltaic cells which rely upon environment conditions particularly generate fluctuating low-voltage electricity. Hence, a front-cease converter for fluctuating low-voltage electricity is required between the low voltage supply and cargo requiring excessive voltage as proven in Fig. 1. The strength potential of these the front-stop converters is typically less than 250W. As the cellular technology advances, the energy ability of front-give up converter should be elevated. It may also reduce the price in step with watt due to the multiplied power capability. As a result, the expanded strength rating of the front-stop converter is needed to cope with massive electricity rating of the advanced cells and decrease the price consistent with watt of the renewable electricity machine [5]. Some of the front-cease converters,

forward/fly back converters that use an active-clamp with voltage double, LLC converters, and segment-shift full-bridge (PSFB) converters are usually not unusual topologies considered for growing electricity capability [6]-[16]. An energetic-clamp circuit correctly realizes the zero-voltage switching (ZVS) for the switches through using the leakage inductance, the magnetizing inductance, and the parasitic capacitance. Especially, forward/fly back converters that use the lively-clamp with voltage double offer the zero-modern-day switching (ZCS) of the diodes of the transformer secondary side because of the resonant-cutting-edge formed with the leakage inductance and the resonant capacitor. But, ahead/ fly back converters have a far better voltage strain across the number one switches of the transformer than the input voltage. Therefore, the MOSFET with low on resistance RDS (on) cannot be hired [17]. With variable frequency manipulate, LLC resonant converter can be hired in all packages with variable enter and output voltages, call for of high performance and power density. But, due to very wide bandwidth, the frequency must be accelerated very excessive to acquire enough voltage advantage controllability. Particularly, traditional LLC resonant topology as the front-quit converter of the micro-inverter is hardly implemented because it is tough to keep excessive performance over fluctuating input voltage with different load situations [18]. The section-shift full-bridge (PSFB) converters are widely used for high efficiency in the medium strength packages. Due to the fact its systems are simple and switches are operated with smooth switching without extra components [19], [20]. but, below the fluctuating input voltage, the whole-bridge converter with the section-shift control scheme isn't always appropriate due to the fact its manipulate scheme has some serious hazards consisting of a slim ZVS variety of the lagging leg switches, duty cycle loss, huge circulating present day loss, and voltage spikes throughout the output diodes. Specifically, the big voltage spike is very severe hassle in the packages which require excessive voltage [21]. To triumph over the trouble of the slim ZVS range below the fluctuating input voltage, the freewheeling length is greater required? Then, the conduction loss of the number one aspect is increased by using the considerable circulating modern. The turn-off switching losses of the lagging leg switches are also expanded. Additionally, ZVS operation of the lagging leg switches cannot be assured below the light load condition because of the inadequate power that's stored inside the leakage inductor. Therefore, to remedy issues of ZVS operation, additional devices are commonly brought. However, these devices which might be employed to extend ZVS variety can bring about increasing the conduction losses and responsibility-cycle loss [22], [23]. The PSFB converter in [24] offers huge ZVS variety of the lagging leg switches and reduces the circulating modern-day at some point of the freewheeling length because of the resonance among the leakage inductance and the output capacitor. However, the constrained resonant frequency can reason excessive contemporary stresses. As a consequence, the traditional PSFB converter with the additional clamping circuit is likewise now not suitable for fluctuating enter voltage. As mentioned above, the conventional PSFB converters cannot satisfy excessive performance in fluctuating input voltage due to the fact extra gadgets for ZVS operation result in the complex circuit structure and the energy losses [25]-[27].

This paper proposes a complete-bridge converter with APWM control that is constant-frequency technique, which achieves ZVS flip-on of the switches and ZCS flip-off of the output diode by using utilizing resonance of the additives. The voltage stresses across the energy switches (S1-S4) of the number one facet are clamped to the input voltage and the voltage pressure of the output diode is likewise reduced without any voltage spike. Usually, APWM control scheme has the stress with unbalance of the output components and the opposite restoration trouble of the secondary side of the transformer. But, in the proposed APWM complete-bridge converter, these problems can be eliminated by using ZCS turn-off. The circulating current loss is likewise removed on the number one side of the transformer because there may be no freewheeling length, that's especially worthwhile for high efficiency underneath fluctuating input voltage than the traditional front-end converters. Therefore, the proposed

APWM full-bridge converter is extra appropriate for programs requiring excessive efficiency over fluctuating input voltage.

II. EVALUATION OF APWM COMPLETE BRIDGE CONVERTER

A. Circuit Configuration and Operation principle

With the exhaustion of the worldwide sources and the environmental pollution, the research at the renewable power assets which includes fuel cells and photovoltaic cells has been regularly prolonged in commercial enterprise fields [1]-[4]. Usually, the renewable strength resources generate low-voltage electricity. The photovoltaic cells which rely upon surroundings conditions mainly generate fluctuating low-voltage energy. As a result, a front-end converter for fluctuating low-voltage strength is required among the low voltage supply and load requiring excessive voltage as demonstrated in Fig. 1. The power potential of these the front-stop converters is usually much less than 250W. Because the mobile generation advances, the strength capacity of front-give up converter ought to be accelerated. It could additionally lessen the price in keeping with watt due to the elevated strength capability. As an end result, the extended energy score of the front-stop converter is needed to cope with huge electricity score of the superior cells and decrease the fee regular with watt of the renewable electricity device [5]. Some of the front-quit converters,

forward/fly back converters that use an lively-clamp with voltage double, LLC converters, and segment-shift full-bridge (PSFB) converters are commonly not unusual topologies taken into consideration for developing energy capability [6]-[16]. A lively-clamp circuit efficiently realizes the 0-voltage switching (ZVS) for the switches via the usage of the leakage inductance, the magnetizing inductance, and the parasitic capacitance. Mainly, forward/fly back converters that use the lively-clamp with voltage double provide the 0-modern-day-day switching (ZCS) of the diodes of the transformer secondary aspect because of the resonant-5bf1289bdb38b4a57d54c435c7e4aa1c shaped with the leakage inductance and the resonant capacitor. However, in advance/ fly back converters have a far better voltage strain across the primary switches of the transformer than the enter voltage. Consequently, the MOSFET with low on resistance RDS (on) cannot be employed [17]. With variable frequency manage, LLC resonant converter can be employed in all packages with variable enter and output voltages, call for of high overall performance and power density. However, due to very extensive bandwidth, the frequency have to be elevated very excessive to acquire enough voltage advantage controllability. Specifically, conventional LLC resonant topology because the front-quit converter of the micro-inverter is hardly ever implemented because it is tough to keep immoderate performance over fluctuating input voltage with distinct load situations [18]. The phase-shift complete-bridge (PSFB) converters are extensively used for high performance in the medium energy packages. Because of the truth its systems are simple and switches are operated with smooth switching without greater components [19], [20]. but, below the fluctuating enter voltage, the complete-bridge converter with the segment-shift manipulate scheme is not suitable because of the fact its manage scheme has some extreme dangers inclusive of a slender ZVS style of the lagging leg switches, obligation cycle loss, massive circulating modern-day loss, and voltage spikes at some point of the output diodes. Specifically, the large voltage spike is very intense trouble inside the applications which require immoderate voltage [21]. To overcome the hassle of the narrow ZVS variety below the fluctuating input voltage, the freewheeling period is more required. Then, the conduction loss of the number one element is increased with the aid of the usage of the sizeable circulating cutting-cutting modern. The flip-off switching losses of the lagging leg switches are also accelerated. Additionally, ZVS operation of the lagging leg switches can't be confident below the light load circumstance due to the insufficient power that is stored inside the leakage inductor. Therefore, to treatment troubles of ZVS operation, additional gadgets are usually introduced. However, those devices which might be hired to increase ZVS range can bring about increasing the conduction losses and obligation-cycle loss [22], [23]. The PSFB converter in [24] offers huge ZVS variety of the lagging leg switches and decreases the circulating modern-day-day at some point of the freewheeling duration because of the resonance many of the leakage inductance and the output capacitor. But, the constrained resonant frequency can purpose excessive current stresses. Therefore, the conventional PSFB converter with the additional clamping circuit is likewise not suitable for fluctuating input voltage. As referred to above, the traditional PSFB converters cannot fulfill immoderate overall performance in fluctuating input voltage because of the fact more gadgets for ZVS operation bring about the complicated circuit structure and the strength losses [25]-[27].

This paper proposes an entire-bridge converter with APWM manipulate this is constant-frequency method, which achieves ZVS turn-on of the switches and ZCS turn-off of the output diode with the aid of the usage of using resonance of the additives. The voltage stresses across the energy switches (S1-S4) of the number one side are clamped to the enter voltage and the voltage pressure of the output diode is likewise reduced with none voltage spike. Commonly, APWM manage scheme has the strain with unbalance of the output additives and the alternative healing problem of the secondary aspect of the transformer. But, inside the proposed APWM complete-bridge converter, those problems may be eliminated by way of the use of ZCS turn-off. The circulating current loss is also removed on the primary side of the transformer due to the fact there can be no freewheeling length, it's in particular profitable for high efficiency under fluctuating input voltage than the conventional the front-end converters. Therefore, the proposed APWM full-bridge converter is more suitable for applications requiring immoderate efficiency over fluctuating input voltage.

III. SOFT SWITCHING CONDITIONS

A. *ZVS condition of the power switches*

For ZVS turn-on of S1 and S4, the primary current ip (t1) must be terrible before S1 and S4 are grew to become on. Consequently, from (15), ZVS condition may be expressed as follows

For ZVS turn-on of S1 and S4, the primary contemporary ip (t1) need to be negative before S1 and S4 are became on. Thus, from (15), ZVS condition can be expressed as follows

The left facet phrases of (22) is continually advantageous no matter load versions. Therefore, ZVS operation of the switches S2 and S3 can usually be happy.

Another ZVS turn-on operation requires a sufficient lifeless time between transfer pairs to without a doubt discharge the voltage throughout the output capacitance Cuss of the switches. Due to the fact ip (t1) =imp (t1) is seemed as constant fee throughout the lifeless-time, the minimum dead time Tread may be calculated as

From (15) and (16), the primary cutting-edge ip (t3) is always larger than the absolute price of the primary modern ip (t1)

B. ZCS situation of the output diode

To obtain the ZCS turn-off circumstance of the output diode Do, the resonant angular frequency or should be large than the vital angular frequency RC. Because the essential condition is ip (Tse) =imp (Tse) at Δ2Ts=zero and D=Dax, the vital angular frequency RC can be defined thinking about the negligible lifeless-time period of the electricity switches as follows

In which tS2, min is the minimal turn-on period of the switches S2 and S3. Normally, the magnetizing inductance Lm is typically designed for the magnetizing current imp (t1) to be small terrible cost to limit the conduction loss of the converter. By this assumption, (26) may be obtained as follows

IV. EXPERIMENTAL RESULTS

To affirm the validity of the proposed APWM complete-bridge converter, a 400W prototype as shown in Fig. 7 became implemented and examined the usage of a DSP processor, microchip dsPIC33EP512GM604. The 400W prototype is a kind of software among low input voltage variety and load which calls for better voltage. All parameters of the prototype are correctly designed to gain the extraordinarily efficient underneath low input voltage range. On this segment, design considerations of the proposed APWM complete-bridge converter are discussed for its excessive performance operation with tender switching approach, and experimental waveforms constitute smooth switching of electricity switches and output diode. Further, the measured electricity performance are offered in line with the enter voltage and the output electricity.

A. Design Issues

The output voltage and the maximum energy of the APWM full-bridge converter are specific as VO=350V and Po=400W (Roman=306Ω). The duty ratio is selected to be the maximum obligation Dax to cover the most output electricity at the minimal enter voltage. Then, the flip ratio of the transformer is selected from (20) as n=eight (Unpins=6: forty eight). From ZVS flip-on condition

(21) Of the switches S1 and S4, the magnetizing inductance Lm must be much less than 43μH to assure the ZVS operation of the electricity switches. The better magnetizing inductance induces the decrease root mean square values of the number one and secondary current, which reduces the conduction loss. But, the transformer saturation have to be taken into consideration in the operating frequency. Accordingly, the magnetizing inductance Lm is practically decided on as 28μH and the leakage inductance Ilk is measured as zero.45μH. Cob = 7.6μF can be decided on

through Fig. 6(b). The parameters of the proposed prototype used for the experiment are represented in desk I.

B. Experimental waveforms and performance

According to the input voltage 40V and 80V, Fig. eight and Fig 9 illustrate the experimental waveforms of the present day iS1 and iS2 and the voltage vS1 and vS2 across S1 and S2 at complete load. Whilst the switches S1 and S2 are turned on, the present day iS1 and iS2 go with the flow via the anti-parallel diode of each switch. As a result, all power switches gain ZVS in the interim of the flip-on, and the voltages vS1, vS2 are clamped to the enter voltage Vdd. As shown in Fig. 10, the output current ion is zero before the output diode Do is became-off. As a consequence, the losses because of the reverse- recovery problem are absolutely eliminated. Fig. 11(a) indicates the measured efficiency in line with the variable input voltage. To reveal the strength-loss breakdown, the calculated loss distributions of the foremost additives in desk II are represented. The energy loss in Fig. 11(a) is similar to the calculated general loss at the input voltage 40V in table II. The proposed converter has high efficiency in the variable enter voltage. When the input voltage is 50V, the proposed APWM full-bridge converter has the maximum efficiency at the rated strength 400W. Fig. 11(b) indicates measured performance in step with the output strength at the enter voltage 50V. The measured efficiency represents that the proposed APWM complete-bridge converter has higher performance than the traditional ahead/fly back converters that use the active-clamp with voltage double over almost all load situation.

V. CONCLUSION

On this paper, APWM full-bridge converter for the renewable power conversion systems that may range between the input voltage 40V and 80V has been proposed beneath ZVS and output diode operates under ZCS without extra components. Additionally, all energy switches are clamped to the enter voltage. Accordingly, the proposed converter has the shape to reduce electricity losses. Those advantages make the proposed converter appropriate for fluctuating input voltage on renewable power conversion structures. The prototype of the APWM full-bridge converter are furnished to validate the proposed concept. Most efficiency of ninety six.8% is acquired on the enter voltage 50V and the rated strength 400W.

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