Interleaved High Step-Up Converter with High Efficiency for Renewable Energy Application

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Applications

Abstract-*A new super-boost converter, which is appropriate for renewable energy applications, is proposed in this paper. The proposed converter consists of switched capacitors and two coupled inductors. This combination can provide a relatively high voltage boost gain while operating with small duty cycle. The converter can be powered either by one individual DC voltage source in an interleaved manner or two independent DC voltage sources as a multiport converter. The configuration of the proposed converter has advantages such as low power losses, longer lifetime of input sources due to non-pulsating input current, low voltage stress across the main switches and slight output voltage fluctuation. Using this converter, a 22.5 times gain can be reached with 0.6 duty ratio and turns ratio equal to 2 that makes it possible to connect a 20Y PY system to a 450Y DC bus. Theoretical analysis and simulation results are presented to demonstrate the authenticity of the proposed converter.*

Introduction:

Today due to the limited resources of fossil fuels and also their serious environmental impacts including greenhouse gas emissions, global warming and environmental pollution, the renewable technologies such as photovoltaic CPY) systems, fuel cells and wind energy systems have received extensive attention as sustainable and clean sources of energy. Among renewable energy sources, PY systems are predicted to become the largest target for energy investment by year 2040 owing to the clean, efficient, and environmentally friendly performance. Since PV cells generate low output voltage, a high step-up DC/DC converter is necessary to boost the PV voltage to a level of DC load/micro-grid voltage or required level of inverter DC-link voltage supplying an AC load/utility. Fig 1. shows typical photovoltaic systems including PV array, a step-up converter and an inverter for converting the DC voltage for AC applications.

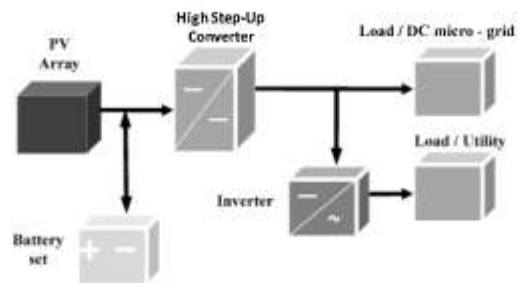

Fig1:Typical photovoltaic system

Generally, high voltage boost gain cannot be achieved using conventional step-up converters since the parasitic parameters will set an upper limit on the duty ratio at which the converter can efficiently operate. In recent years many high step-up DC-DC converters have been proposed. Among the developed converters, the high step-up single switch converters exhibit large input current ripple which make them unsuitable to operate at heavy load due to high conduction losses. An alternative solution for high power applications is conventional two-switch interleaved step-up converter. Although the conventional interleaved converter alleviates the input current ripple, similar to the conventional boost converter it has not been developed for handling high voltage boost gain. The limited step-up gain could be overcome by integrating the coupled-inductor into the interleaved converter. The switch voltage stress is also reduced by the transformer function of the coupled-inductor. However, in order to achieve an extreme voltage gain, it is required to increase the turn's ratio of the coupled inductor which affects the transformer linearity and increase the leakage inductance causing the voltage spike across the switches during the off state. Extreme voltage gain can also be realized through diode-capacitor voltage multiplier. This solution has allowed the DC-DC converter to operate with low input current ripple which is suitable for high power application. Nevertheless, many cascaded diode-capacitor voltage multipliers are needed to increase the voltage gain, thus, the converter efficiency would be affected for high voltage gain. In this paper, a new high step-up DC-DC converter is proposed. The proposed converter can be powered either by one individual DC voltage source in an interleaved manner or two independent DC voltage sources as a multiport converter. This converter combines the advantages of the coupled inductors with the diode-capacitor multipliers and hence a super step-up gain can be easily achieved with minimum number of multipliers and low turns ratio of the coupled inductors while the converter operates at low duty ratio. The proposed converter exhibits high efficiency in a wide range of operation. It also presents low current ripples and low conduction losses which make it able for high power applications. In addition, the voltage stress across the switches and diodes is much lower than the output voltage.

Existing system:

A unique high change of magnitude device that is appropriate for renewable energy system is planned during this paper. Through a voltage multiplier factor module composed of switched capacitors and coupled inductors, a standard interleaved boost device obtains high change of magnitude gain while not in operation at extreme duty quantitative relation. The configuration of planned device not solely reduces the current stress however additionally constrains the input current ripple, which decreases the physical phenomenon losses and elongates the life time of input supply. Additionally, because of the lossless passive clamp performance, escape energy is recycled to the output terminal. Hence, massive voltage spikes across the most switches area unit alleviated and therefore the potency is improved. Even the low voltage stress makes the low-voltage-rated MOSFETs may be adopted for reductions of physical phenomenon losses and value. Finally, the model circuit with a 40- V input voltage, 380- V output, and 1000- W output power is operated to verify its performance. the best efficiency is 97 %.Theoretically, standard change of magnitude converters, like the boost device and fly back device, cannot attain a high change of magnitude conversion with high potency thanks to the resistances of components or run inductance, additionally the voltage stresses square measure massive. Thus, in recent years, several novel high step- up converters are developed. Despite these advances, high change of magnitude single-switch converters square measure unsuitable to operate at significant load given Associate in nursing input massive current ripple, which will increase conductivity losses. Standard interleaved boost device is a superb candidate for high-energy applications and power issue correction (PFC). Sadly, the change of magnitude gain is restricted, and therefore the voltage stresses on semi-conductor parts square measure adequate to output voltage. Hence, based on top of concerns, to change standard interleaved boost device for top change of magnitude and high-energy application could be anappropriate approach. To integrate switched capacitor into interleaved boost device could build voltage gain reduplicate.however, while not employment of coupled-inductor causes the change of magnitude voltage gain restricted. Oppositely, to integrate solely coupled inductance into interleaved boost converter is in a position to create voltage gain higher and adjustable, but while not employment of switched electrical condenser causes the step- up voltage gain standard. Thus, the synchronous employment of coupled inductance and switched electrical condenser could be a better thought, additionally because the high change of magnitude gain, high potency and low voltage stress square measure achieved even for top power applications. The projected device could be a standard interleaved boost converter integrated with a voltage multiplier factor module, and the voltage multiplier factor module consists of switched capacitors and coupled inductors. The coupled inductors will be designed to extend change of magnitude gain, and therefore the switched capacitors offer further voltage conversion magnitude relation. additionally, once one of the switches turns off, the energy holds on in magnetizing inductance can transfer via 3 several methods, thus, this distribution not solely decreases the conductivity losses by lower effective current, however additionally makes currents through some diodes decrease to zero before they put off, that alleviate diode reverse recovery losses.

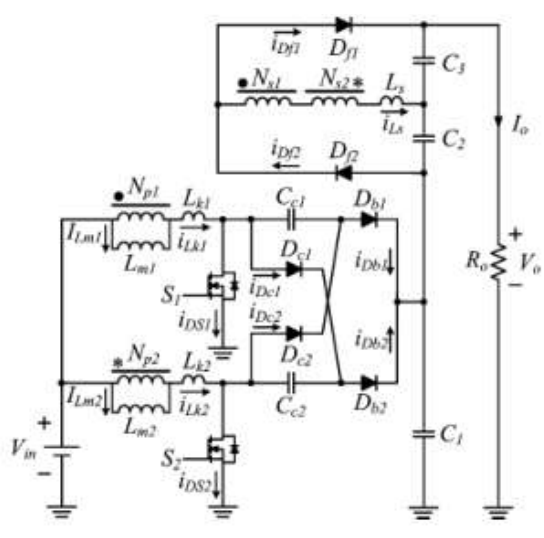

Fig 2:proposed interleaved high step up converter

The projected high change of magnitude interleaved device with voltage multiplier factor module is shown in Fig3. The voltage multiplier module consists of 2 coupled inductors and two switched capacitors, and is inserted between conventional interleaved boost devices to create Associate in nursing changed boost-fly back-forward interleaved structure. When the switches put off by flip, the part whose switch is off-state performs as a fly back device, and therefore the alternative part whose switch is on-state performs as a forward device. Primary windings of the coupled inductors with N p turns square measure employed to decrease input current ripple, and secondary windings of the coupled inductors with N s turns square measure connected in series to increase voltage gain. The turn's ratios of the coupled inductors square measure identical. The coupling references of the inductors square measure denoted by '.' and '*'.

Proposed System:

The planned interleaved high increase device is shown in Fig.2 The device consists of 2 coupled-inductors and four diode-capacitor voltage number (DCVM) stages. Each DCVM stage consists of 1 diode and one electrical device. The DVCM stages are inserted between the input and output stages of the device to boost the voltage conversion ratio. By increasing the amount of DCVM stages, it's doable to reach a better voltage gain at constant duty quantitative relation. However, for simplicity and higher understanding, four DCVMstages are used. The coupled inductors are resided within the proposed device in order that a changed fly back-forward interleaved structure is made. the first windings of the coupled inductors with np1 and np2 turns are utilized within the input stage to decrease the input current ripple, whereas the secondary windings with nsl and ns2 turns are connected in series with the output stage to enlarge the voltage gain. the coupled inductors have an equivalent turns quantitative relation. The coupled inductance may be sculptured because the combination of a magnetizing inductance, a perfect electrical device and series leakage inductors in every winding. The equivalent circuit of the planned device is shown in Fig. 3, wherever Lm1 and Lm2 are the magnetizing inductances, Lip1 and Lip2 are the first windings run inductances, Lis is that the summation of secondary windings run inductances, SI and S2 are power switches, Coutl, Cout2 and Cout3 are the output capacitors, CI to C4 and DI to D4, severally, indicate the capacitors and therefore the diodes of DCVM stages, Df1 and Df2 are the output diodes of the fly back-forward structure and n denotes turns quantitative relation np/ns. In the circuit analysis, it's assumed that the device operates in continuous conductivity mode (CCM) and therefore the duty ratio of the switches is bigger than 0.5. Fig4. illustrates the operational waveforms of the planned device in CCM during one switch cycle. Because it is shown within the figure, there are some overlapping time once 2 switches are ON and also your time intervals once just one of the switches is ON. six operation modes exist in every switching cycle for the planned device.

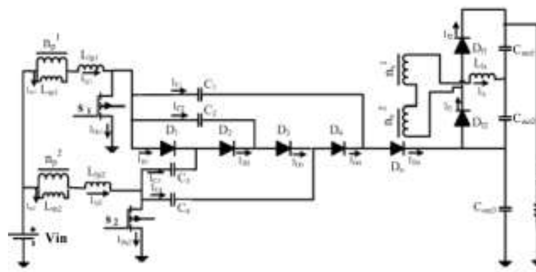

Fig3: The equivalent circuit converter with predecessors and magnetic leakage.

Mode I [to, t1]:

At t = to, while the power switch S2 remains ON, the power switch SI is switched ON. The diodes D1-D4, Do and D_{f1} are reverse biased as shown in Fig. 5(a). During this mode the energy stored in the series leakage inductance L1s is completely discharged into the output terminal through fly back-forward diode Df2and iLS decreases to zero; hence, the leakage inductor current ilp1 linearly increases and the leakage inductor current ilp2 inversely decreases.

Mode II [t_1, t_2]:

At t = t_1, the power switches S1 and S2are still ON and all of the diodes are reverse biased. Therefore, both the primary leakage inductances and the magnetizing inductances are charged by the input source and the currents i_{lp1}, i_{lp2}, img1 and img2 linearly increase.

Mode III [t2, t3]:

At t = t2, the power switch S2 is turned OFF while the switch SI remains ON. the diodes DI, D3, Do and Df2 are reverse biased in this mode and Lm1 and LIp1 are still charged through the input source. In contrast, the energy stored in the Llp2 releases into the capacitors CI to C4 and the energy stored in Lm2 is transferred to the secondary side of the coupled inductor and charges the output capacitor through the diode Dfl.

Mode IV [t3, t4]:

At t = t3, the power switch SI remains ON whereas the power switch S2 is switched ON. The diodes D1-D4, Do and D_{f2} are reverse biased in this mode. The energy stored in Lm1 is transferred to the secondary side of the coupled inductor and the output capacitors are charged through Df1

Mode V [t4, t5]:

At t = t4, both of power switches SI and S2 remain ON. All of diodes are reverse biased in this mode. The current of the leakage inductances Lip1 and Llp2 linearly increases by the input source.

Mode VI [t5, t6]:

At t = t5, the power switch S2 remains on-state while the power switch SI is turned off. The diodes D2, D4 and Df1 are still reverse biased, whereas the diodes DI, D3, Do and Df2 are turned ON. The energy stored in Lip1 and CI is released to the output capacitor Cout3 through Do. Moreover, a part of the energy stored in Lip1 charges C2 and C3 and the energy stored in Lm1 is transferred to the secondary side of the coupled inductor and charge Cout2.

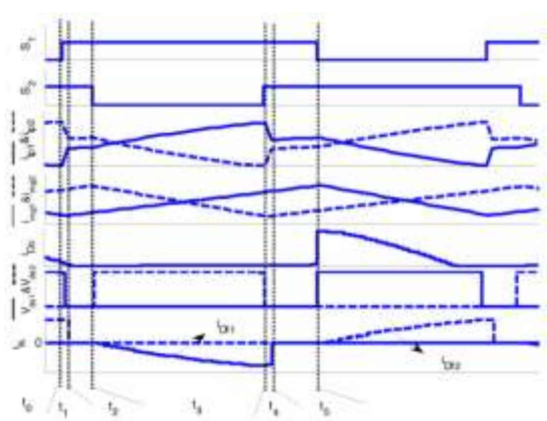

Fig. 4. Operational waveforms of the proposed converter in CCM

Steady state analysis of proposed converter:

In order to simplify the circuit analysis of the proposed converter, some assumptions are made as follows.

1. All of the circuit components are considered ideal and there is no power loss in the system.

2. The proposed converter is operating in CCM and in the steady-state condition.

3. The leakage inductance of the coupled inductors are neglected.

4. The capacitors are sufficiently large, such that the voltages across them are considered as constant.

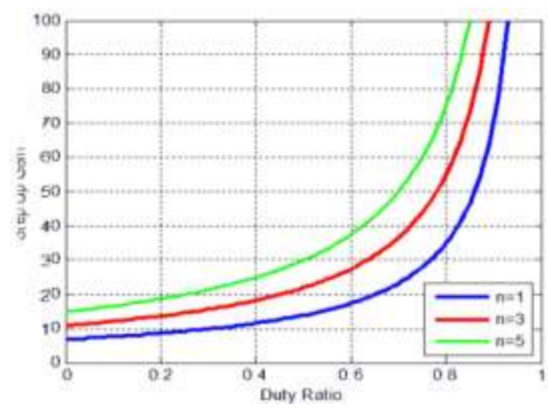

Fig 5: The voltage gain based on turns ratio and duty cycle

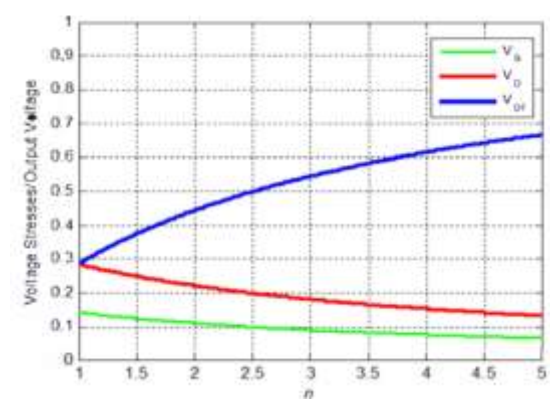

Fig 6: The voltage stresses on semi-conductor components based on turns ratio n.

Simulation results:

In this section, simulation results of a lkW DC/DC system are presented to verity the effectiveness of the proposed converter. The simulation waveforms of the projected converter in steady state condition. Fig8 displays the interleaved PWM signals of power switches. because it is often seen in the figure, the duty magnitude relation of the switches is adequate to 0.6.The voltages across C2 and C3 are terribly near the expected voltage level. The voltages across CI and C4 have additionally settled at the anticipated levels. This is as a result of those non-ideal components are thought of within the simulation, whereas the steady state analysis in section III has dispensed beneath the assumption of the system is lossless. The voltages across Coutl and Cout2 are pictured. As it can be seen, the output voltage is regulated to 870 V, thus the voltage gain cherishes the input voltage is concerning 22. Since the turns magnitude relation of the coupled inductors are adequate to two and duty magnitude relation is 0.6, it's expected to possess an increase gain equal to 22.5 A small distinction between the simulation gain and also the calculated gain arises from the actual fact that the impact of parasitic elements wasn't thought of within the steady state analysis. The output voltage of the projected device with n=1 and n=2 are shown in Fig13,the voltage levels during this figure clearly confirm the theoretical analysis of the projected device.

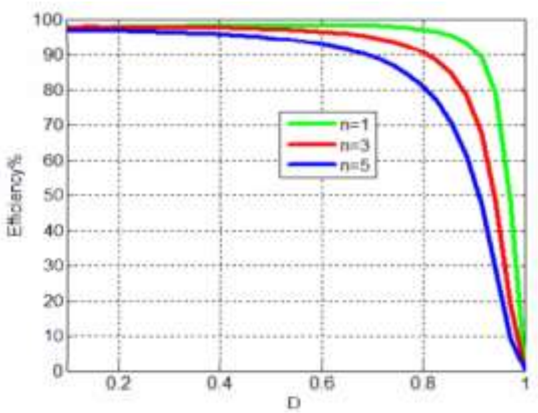

Fig 7: The Efficiency based on turns ratio n and duty cycle.

The simulation waveforms

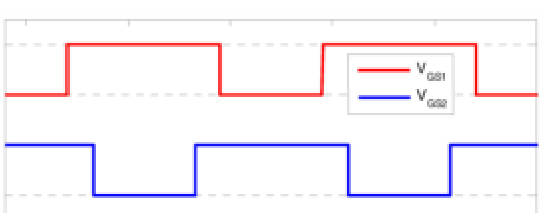

Fig 8: (A) displays the interleaved PWM signals of power switches

Fig 9: (B)show the voltage across the DVCM stage capacitors vc3 & vc2

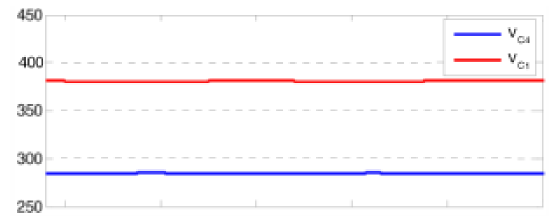

Fig 10: (C) show the voltage across the DVCM stage capacitors vc4 & vc1

Fig 11:(D)shows voltages across Coutl and Cout2 are depicted

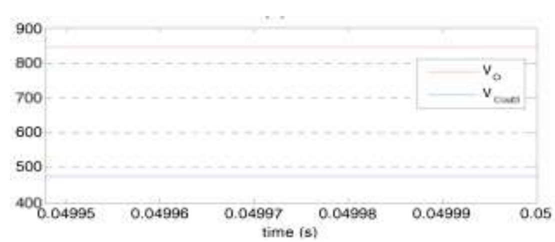

Fig 12: (E) Shows the voltage of Cout3

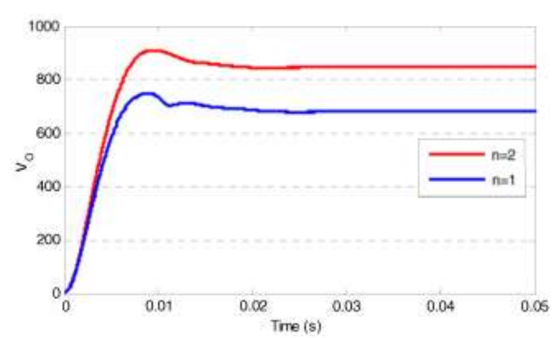

Fig 13: The output voltage with n=l and n=2

TABLE I. performance comparison among interleaved high step-up converters

High step up interleaved converters	Converter in [8]	Converter in [3]	Proposed Converter
Voltage Gain	$\frac{2}{1-D}+nD$	$\frac{2(n+1)}{1-D}$	$\frac{2n+5}{1-D}$
Voltage stress on switches	$\frac{Vo}{2+nD(1-D)}$	$\frac{1}{2(n+1)}Vo$	$\frac{1}{2n+5}Vo$
The Maximum Voltage Stress on diodes	$\frac{2Vs}{2+nD(1-D)}$	$\frac{(n+0.5)}{n+1}Vo$	$\frac{2n}{2n+5}Vo$
Number of magnetic cores	3	2	2
Number of Secondary side windings	1	2	1

Comparison between counterpart topologies:

In this section, the results of the comparative analysis of the planned convertor and different interleaved high change of magnitude converter planned and supported voltage gain, voltage stress on semiconductors devices and therefore the range of magnetic cores area unit bestowed. Table I shows the performance comparison among interleaved high change of magnitude converters. As it is obvious within the table I, the planned convertor provides the highest change of magnitude gain between the converters. Moreover, the voltage stress on the semiconductor devices of the planned converter is that the lowest among totally different convertors. In addition, so as to produce same voltage gain with totally different converter mistreatment similar turns quantitative relation; the planned convertor needs all-time low duty quantitative relation that ends up in the minimum conduction losses and thence the utmost potency.

Conclusion:

In this paper a replacement interleaved high change of magnitude convertor is proposed. The planned convertor combines the benefits of the coupled inductors with the diode-capacitor voltage multipliers and thus a brilliant change of magnitude gain is often simply achieved with minimum range of multipliers and low turns ratio of the coupled electrical device whereas the convertor operates at low duty quantitative relation with low current ripples and low conductivity losses. Therefore, the planned convertor exhibits high efficiency during a big selection of operation that makes it appropriate for high power application. The simulations results verify the authenticity of the theoretical analysis and also the effectiveness of the planned system as a brilliant high change of magnitude convertor.

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