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Engineering

A HIGH GAIN DC-DC CONVERTER WITH A FIVE LEVEL INVERTER FOR PV APPLICATIONS

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ABSTRACT High gain DC-DC converters with higher conversion efficiency is necessary for certain applications such as fuel cells, solar photovoltaic systems and uninterruptable power supplies. Here a "High gain dc-dc converter with a five level inverter" topology is proposed. The secondary sides of the coupled inductors in the converter are in interleaved series connection and shared by two voltage-double modules to ensure the interleaved energy storage. In order to achieve high voltage gain, the input voltage, coupled-inductors, and multiplier capacitors are in series connection with the output side. The main objective is to use lesser components to step up as much voltage gain as possible to simplify the complexity of circuit design and analysis. This topology will also reduce the input current ripples, number of components, voltage and current stress across the switches and switching losses. A five level inverter is also added to the system for dc-ac conversion to drive ac loads. The five level inverter reduces the THD in the output. The THD of the five level inverter is compared with conventional H bridge inverter. The simulation of the proposed system is modelled with input voltage of 24V and output voltage of 400V is realized in MATLAB/Simulink.

KEYWORDS : Coupled inductor, Interleaved boost converter, Voltage-double module, Transistor clamped H bridge inverter (TCHB), Maximum Power Point Tracking (MPPT), P&O algorithm.

INTRODUCTION

The requirement for renewable energy has increased significantly over the years due to shortage of fossil fuels and greenhouse effect. Nowadays we are widely depending on renewable energy resources for the benefits provided by clean green energy. Even though renewable, pollution free and environmental friendly, these energy sources are inconsistent. However solar energy is not available during night and availability depending on the duration of the day and the climate conditions. Output falls below considerably even when a small portion of PV module, or array is shaded, while the remainder is in sunlight. That is solar energy is fluctuating in nature. Among different kinds of renewable energy sources, solar energy and wind energy have become widely popular and demanding due to the developments in power electronics techniques. The renewable energy generally belongs to the type of source with low voltage and high current. Therefore, the outputs of these sources needs an efficient and high step-up converter to convert the low-voltage to the application with the necessary higher output voltage (such as the dc bus of the microgrid, the high-voltage dc loads, the dc input of the inverters, etc.) to improve the utilization of the renewable energy. In order to fulfill the requirements, if the conventional boost converter is used, the high voltage gain may not be attained or the converter may be operated at the large duty cycle to make the components sustain the high voltage stress and to increase the conversion loss.

To achieve high voltage gain and better performance condition, 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 demerits of these topologies are, they have high input current ripples. To reduce this problem, interleaved step-up converters with the voltage-double module topology have been proposed. But they need more components and it increases the total cost.

The high gain boost converter topology proposed in this paper uses an interleaved converter with a voltage double module and coupled inductor. The secondary sides of the coupled inductors in the converter section are in interleaved series connection and shared by two voltage-double modules to establish the interleaved energy storage. In order to obtain high voltage gain, the input voltage, coupled-inductors, and multiplier capacitors are in series connection with the output**.** The switching pulses for the converter switches are obtained through MPPT method.

Multilevel inverter topology has developed nowadays as a very important alternative in photovoltaic systems. Recently several multilevel topologies have been proposed, but the drawback is that, as the output voltage levels increases, the number of switches, switching stresses, losses, voltage unbalancing across capacitors also increases. This paper proposes a five level inverter for converting DC energy from the high gain interleaved converter to AC energy for PV applications with less number of switches. As the number of levels increases the total harmonic distortion decreases. Single reference double carrier pulse generation method is used for giving switching pulses to the inverter switches. This PWM switching technique reduces total harmonic distortion. Altogether the proposed system achieve high gain, low input current ripples, lesser components count, low voltage stress across the switches, higher efficiency and reduced harmonic distortion. Therefore the system is best suited for photovoltaic system and other certain applications.

PROPOSED SYSTEM

The overall circuit diagram of the proposed system is shown in Figure 1. The circuit diagram is composed of the DC source (PV array), the DC–DC boost converter, the DC–AC (five levels) inverter, and the load. Solar is a varying DC type of source. Also its output voltage is very low. To convert this low voltage dc to a high voltage dc, an interleaved high gain boost DC-DC converter with a voltage double module and coupled inductor is used. The five level inverter converts the DC output of the converter into AC form with reduced harmonic distortion. The analysis of the converter and inverter are discussed in following sections.

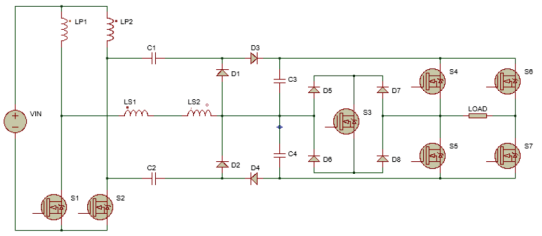

Figure 1: Circuit diagram of proposed system

INTERLEAVED SERIES HIGH STEP- UP DC-DC CONVERTER

Fig.2 shows the proposed interleaved high step-up DC-DC converter. It consists of two coupled inductors, two switches, four diodes and four capacitors. The number of switches is less compared to conventional high gain DC-DC converter circuits. The circuit arrangements can be mainly divided into two parts. The blue block represents the interleaved series converter and the red block represents the interleaved voltage-double modules. The secondary sides of the coupled inductors are in interleaved series type and the two voltage-double modules share the secondary side of coupled inductors

together. The capacitor modules are in series with the input, primary side inductors, and secondary side inductors to charge the output capacitor.

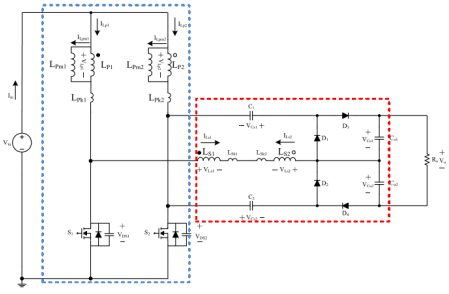

Figure 2: Proposed interleaved series high step-up converter

The coupled inductors can also provide electrical isolation. The main advantage of this topology is low input current ripples and low voltage and current stress across the converter switches.

The input of the converter is solar energy. Therefore Maximum power point tracking (MPPT) is needed to realize PV panels. In this paper P&O MPPT algorithm (Perturb & Observe) is used. P& O is the most widely used algorithm to track maximum power due to its simplicity. This technique operates by regularly perturbing PV module voltage and comparing output power of PV with previous perturbation. The gate triggering pulse for the converter is generated by using this technique.

FIVE LEVEL INVERTER CIRCUIT

Fig.3 shows the transistor clamped five level inverter. It consists of a normal H bridge inverter and an auxiliary circuit of single switch is combined. TCHB multilevel inverter can produce more output levels with lesser number of switches. As the number of levels increases, total harmonic distortion decreases and efficiency increases.

A. Modes of operation

The five output voltage levels can be generated as follows

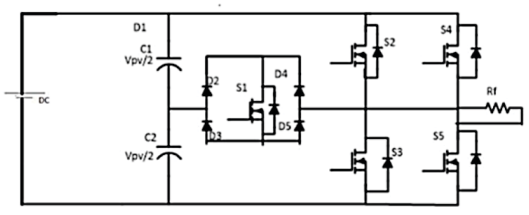

Figure 3: Proposed five level inverter circuit

1) Level V_{dc}: The switch S2 is in ON condition, connects the positive load terminal to V_{dc}, and switch S5 is also in ON state, connects the negative load terminal to ground. The other switches are in OFF condition, thus the applied voltage to the load terminals is V_{dc}

2) Level $V_{dc/2}$: The switches S1 and S5 is ON and the other switches are OFF. The voltage applied to the load terminals is $V_{dc/2}$

3) Zero output: The two switches S3 and S5 are in ON state, short-circuiting the load. All other switches are OFF; the voltage at the load terminals is zero.

4) Half-level negative output, $V_{dc/2}$: The switch, S1 is ON and S4 is ON and the other switches are OFF. The voltage at the load terminals is $-V_{dc/2}$

5) Maximum negative output: The switch S4 is ON and S3 is ON and the other switches are OFF. The voltage applied to the load terminals is $-V_{dc/2}$

The switching states of the proposed TCHB inverter is given in table 1.

The triggering of switches can be done by PWM method in simulation. Logical operators are used to develop the pulses for five switches of the inverter in order to satisfy the switching condition. Also care must be taken to avoid unwanted triggering of switches.

Table 1: Switching states of proposed inverter

LEVELS	S1	S2	S3	S4	S5	OUTPUT VOLTAGE
1	0	0	1	0	1	0
	0	0	0	1	1	
2	1	0	0	0	1	+Vpv/2
3	0	1	0	0	1	+Vpv
4	1	0	0	1	0	-Vpv/2
5	0	0	1	1	0	-Vpv

B. Control scheme

The control scheme adopted for triggering the five switches of the five level inverter is shown in Figure 4. This is single reference double carrier PWM method.

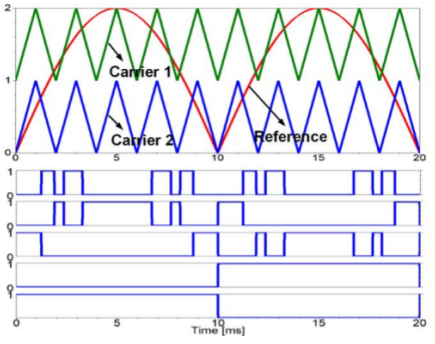

Figure4:Single reference double carrier PWM scheme

In this method two triangular carrier waves are compared with a single reference signal. The pulsing method comes under phase disposition technique. Here both the carrier signals are compared with single

reference signal. The gate signals are obtained by using logical operator.

SIMULATION RESULTS

The proposed system is simulated and analyzed in MATLAB/ Simulink. The simulation of the overall proposed system is shown in Figure 5.

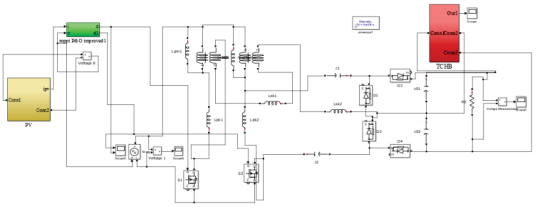

Figure 5: Simulation model of proposed system

For the converter a voltage of 24V is given as the input. This is done by PV modelling. Fig 6. Shows the input voltage waveform of proposed converter. For a 24V input an output of 400V is obtained. That means the gain of the proposed converter is very high. Figure 7 shows the output voltage waveform of dc-dc converter.

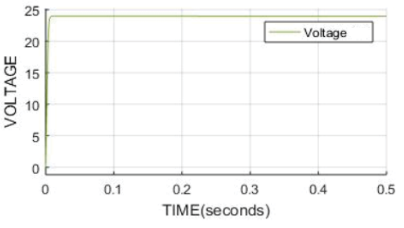

Figure 6: Input voltage of the dc-dc converter

Since the source is PV module, in order to obtain maximum power, perturbance and observe (P&O) algorithm is used. The gate pulses for the two switches of the converter is shown in Figure 8.

Figure 9: Shows the waveform of the voltages across the converter switches. From the waveform it is clear that the voltage across the switches can be known to be about 60V. So that, the switch with the lower rating and conduction resistance can be applied to reduce the loss and increase the efficiency.

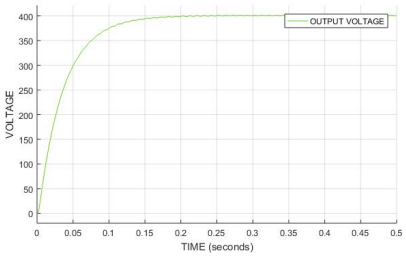

Figure 7: output voltage of the dc-dc converter

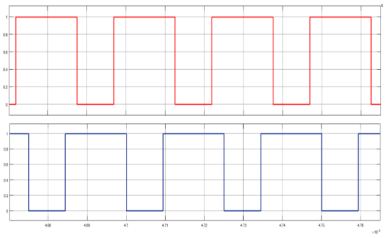

Figure 8: Waveform of switching pulses for converter

The main advantage of the proposed converter using coupled inductor is its low input current ripples. Figure 10 shows the input current waveform of the proposed converter. The current ripple obtained is about 10% of the total input current.

The Figure 11 shows the output voltage waveform of the five level inverter. The five levels are obtained in the output waveform. Also each level is equal in magnitude.

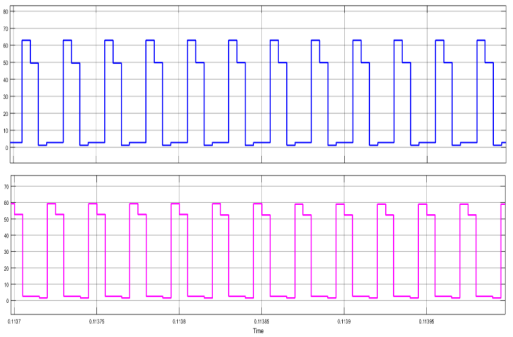

Figure 9: Waveform of voltages across the converter switches

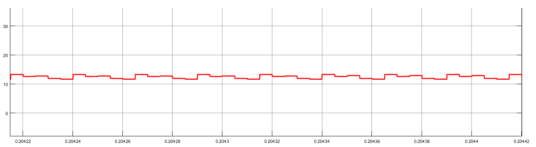

Figure 10: Waveform of input current of dc-dc converter

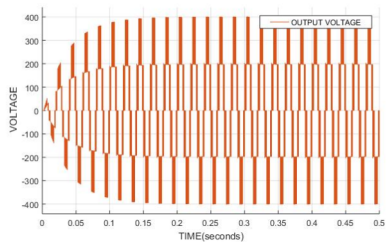

Figure 11: output voltage waveform of five level inverter

The switching pulses for the TCHB multilevel inverter is generated using double carrier single reference PWM scheme. The switching pulses for the five switches are shown in Figure 12.

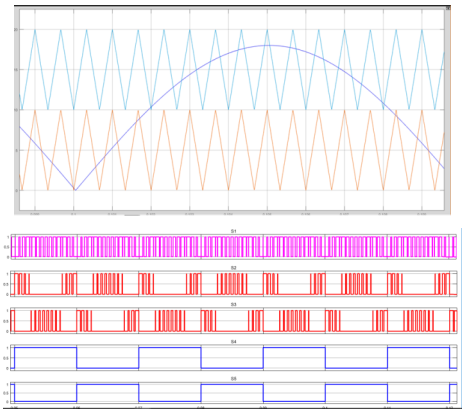

Figure 12: Switching pulses for inverter switches

THD COMPARISON OF THE PROPOSED INVERTER AND CONVENTIONAL H BRIDGE INVERTER

The THD of the output voltage waveform of proposed inverter is shown in Figure 13. The THD is about 2.04%.

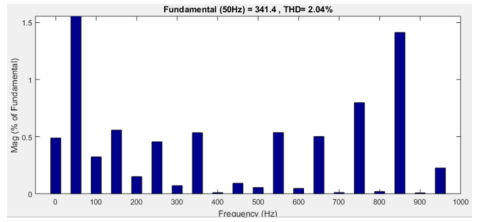

Figure 13: THD of output voltage of proposed inverter

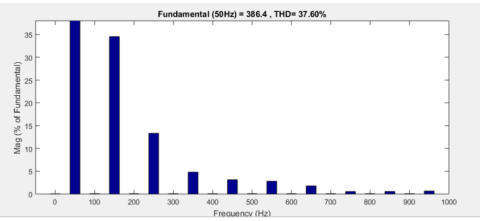

Figure 14: THD of output voltage of conventional H bridge inverter

The THD of the H bridge inverter is obtained as 37.60%, which is very much high compared to proposed five level inverter. From the analysis it is clear that the system offers higher efficiency of greater than 90%.

CONCLUSION

This paper introduces a new interleaved series high step-up converter with a five level inverter for photovoltaic applications. The main objective is to achieve higher voltage gain using lesser components to reduce the complexity of circuit design and analysis. The current sharing is achieved through interleaved structure and reduce the current and voltage stress of the components. It also reduces the input current ripples. The proposed converter is operated at an input voltage of 24V and produces an output of 400V. The modified five level inverter with lesser number of components ensures lower THD of the output voltage waveform. The combined system guarantee high voltage gain, lower input current ripples, lesser components, low voltage and current stress of the components, lower rating and cost, reduced harmonic distortion and also higher efficiency.

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