Off-Grid Solar System with Interchangeable High Gain AC and DC in the same line

P.U.Ganesh\textsuperscript{1}, S.Deepa Rohini\textsuperscript{2}

\textsuperscript{1}Department of Electrical and Electronics Engineering, Sri Sai Ram Engineering College, Chennai, India
\textsuperscript{2}Assistant Professor, Department of Electrical and Electronics Engineering, Sri Sai Ram Engineering College, Chennai, India
dbganesh360@gmail.com\textsuperscript{1}, deepa.eee@sairam.edu.in\textsuperscript{2}

Abstract—this paper proposes a new technique to obtain either the AC or DC output from the same two terminals without having to tap before an inverter to obtain the DC. The DC-DC converter used will be a modified Z-source DC-DC booster which will be having a high voltage gain for small duty cycles. The AC or DC changeover circuit used will be an H-Bridge Circuit which will be used to obtain AC or DC output depending upon the way the switches are operated. This proposed idea will be verified through a simulation.

Keywords—same two terminal line, No tapping for DC before inverter, Interchangeable AC or DC.

1. INTRODUCTION
In today’s world global warming has become a big crisis, so many investors are looking for green energy sources that can provide them with high efficient output as when they were using non-renewable energy sources. Thus, solar energy, which is very abundant, can be used to meet our requirements. This energy, which is free of pollution, very abundant and free to tap into. But since the solar array outputs low voltage we have to boost up the voltage to some high level to make it usable for our requirements. This process can be done by using a modified Z-Source DC-DC booster to obtain high voltage gain. By going into Off-Grid we will be not connecting the solar panel with the electricity grid and therefore there arise a need for using battery to store the energy. This provides us with energy throughout the year even when the electricity grid has gone for any kind of maintenance and thus increases the reliability.

2.BLOCK DIAGRAM
The PV array is faced towards the sun in a particular angle. To track the sun’s position one can also use sun movement tracker arrangement to track its movement but for low cost budget it would be
enough to face the PV array in a particular angle towards the sun since the hours we will be getting sunlight will be less compare to the actual day cycle hours. The charge controller can be used to charge up the battery by maintaining the particular voltage level constant and it also prevents the battery from becoming overcharged.

Fig.2: Modified Z-Source DC-DC

This stored up energy can be boosted up through a modified Z-Source DC-DC booster with high voltage gain as shown in Fig.2. Both the switches receive the same signal thus there is no complexity signaling the switches. The gain of this booster circuit is \((1+D)/(1-7D)\), thus it boosts up the voltage to high level in low duty cycle thus reducing the switching losses.

![Fig.2: Modified Z-Source DC-DC](image)

\[ V_{c1} = V_{c2} = \frac{1-3D}{1-7D} V_i \]
\[ V_o = V_{c3} = \frac{1+D}{1-7D} V_i \]

Fig.3: AC/DC Converter

Then the boosted output is fed to the AC/DC converter, which gets its signal from the signal generator like microcontroller to decide when to make the output of this converter AC or DC. Thus, the signal generator plays a key role in selecting the mode of output. AC/DC converter is nothing but the H-bridge circuit, which is used for SPWM inverter. By exploiting the working of this bridge circuit we can make the output of this circuit either AC or DC. The output of the AC/DC converter is fed to the LC filter in Pi network configuration thus filtering out the higher frequency and giving us the required sine wave.
3. DC-DC BOOSTER

A. Principle of operation

Some assumptions are made before proceeding to explain the circuit working. It is assumed that the components used in this booster are all ideal, on-state resistance is zero and forward voltage drops are also zero. The capacitors used in this circuit is large enough to make the voltage ripples negligible. This booster operates in continuous current mode. The switches $S_1$ and $S_2$ are turned on simultaneously, so they share the same signal. The operation can be explained in two states. In state one both switches are turned on and in state two the switches are turned off.

**State I:** The switches $S_1$ and $S_2$ are turned on thus making the diodes $D_4, D_2, D_8, D_9$ and $D_6$ are reversed biased, $D_1, D_3, D_5$ and $D_7$ are forward conducted. Because of this the inductor $L_1$ and $L_2$ of the switched inductor network are parallel and they charge the series capacitor $C_1$ and $C_3$; the inductor $L_3$ and $L_4$ are also parallel and they charge the series capacitors $C_2$ and $C_3$; the load will be supplied by the parallel capacitor $C_3$.

**State II:** In this state, the switches $S_1$ and $S_2$ are turned off as a result the diodes $D_4, D_2, D_8, D_9$ and $D_6$ are turned on, $D_1, D_3, D_5$ and $D_7$ are turned off. Because of this the capacitor is charged by the series input source and the switched inductor network $I$ as these two inductors are in series through $D_3$. The capacitor $C_2$ is charged by the series input voltage source and switched inductor network $II$, as same as before. The capacitor $C_3$ is charged by the series input voltages source and the four inductors $L_1, L_2, L_3$ and $L_4$, which also supply the load.

![Voltage Gain](image)

As one can see from Fig. 4, the voltage gain increases drastically at low switching frequency thus high gain at low switching loss can be achieved by this circuit.

B. Design Parameters

The Voltage $V_{c1}, V_{c2}, V_{c3}$ and $V_o$

The inductance $L=L_1=L_2=L_3=L_4$ then the average current is

$$I_\text{av} = \frac{P}{V_s} = \frac{P}{n V_i}$$

The average inductor current can be obtained as
In state $I$, both the inductors $L_1$ and $L_2$ are charged by the capacitors $C_1$ and $C_2$, along with the capacitor $C_3$. The current ripple through each inductor can be obtained as

$$I_L = \frac{P_s}{nV_i(1-D)}$$

Considering the fact that a $x_4$% peak-peak ripple current is tolerable for the inductor, the inductance can be then calculated by

$$\Delta I_e = \frac{(V_{C1} + V_{C2})D}{I_f}$$

Peak-peak capacitor ripple voltage can be calculated by

$$\Delta V_{C} = \frac{I_{L}D}{Cf_s}$$

The capacitance $C=C_1=C_2$ then the voltage ripple on each capacitor can be obtained, according to state $I$, as

$$\Delta V_{C} = \frac{I_{L}D}{Cf_s}$$

4. AC/DC CONVERTER

A. Principle of operation

This H-bridge circuit is the key component for conversion between AC or DC. So this working can be split into two parts, one when it was giving AC and the other when it was giving DC.

AC Output: When this converter has to give out AC output the electronic switches in the opposite legs are given positive half cycle SPWM signals and negative half cycle SPWM signals thus the output will be a sine wave when it has been filtered by the LC filter.

DC Output: When this converter has to give out DC output any one pair of the electronic switches has to be signaled by a constant signal without any modulation. Thus the switches will be permanently turned on and the output polarity will not be reversed since the other pair of switches will not be turned on. Thus the same terminal which used to supply AC now supply DC.
Thus one can get both the AC or DC in the same two terminals

B. Design Parameters

![Fig.5: SPWM Signal](image)

![Fig.6: H-Bridge Circuit](image)

The L and C value for the filter is found out by the relation

\[ f = \frac{1}{2\pi\sqrt{LC}} \]

Where f is the cut-off frequency.

5. SIMULATION

To verify the feasibility of the proposed technique, a prototype is simulated in MATLAB software. The simulation parameters are designed as follows: The solar PV array output is assumed to be a constant DC voltage source coming out of the charge controller to the booster circuit. The input voltage to the booster circuit is 12V; the operational frequency is 25kHz; the inductance of the inductor used in the DC-DC booster circuit is 300µH and capacitance of the capacitors is 330µF and the capacitor used between the booster and AC / DC converter is 1000µF. For the LC filter the
The inductance and capacitance used is 60mH and 0.75µF. The resistive load of 100Ω is taken. A parasitic resistance of 10mΩ is considered in series with the inductor and capacitor and the same 10mΩ turn on resistance is considered for the MOSFETs.

**Fig.7: AC Mode**

**Fig.8: Waveform in AC Mode**

**Fig.9: DC Mode**

**Fig.10: Waveform in DC Mode**
As seen in Fig.7 When the switches are signaled in SPWM signal the output of the AC / DC Converter will be AC which can be seen in Fig.8 but when the same switch is signaled by a constant signal as per Fig.9 the AC / DC Converter output will be as per the Fig.10. thus the proposed idea has been verified using MATLAB simulation software.

6. CONCLUSION

This kind of technique will be very useful in the testing industry and colleges were they can get either AC or DC output from the same terminal thus preventing the need for separate panels for AC and DC. In industry this idea can be implemented to run emergency equipment’s which runs on DC during emergency situation and AC equipment’s which runs during normal situation. Thus the cost can be reduced greatly which will be profitable for the organization.

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