BOOST CASCADED BUCK CONVERTER FED PHOTOVOLTAIC INVERTER

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Abstract
This paper is about a new boost cascaded buck converter fed photovoltaic inverter. This method can be applied for all type of non renewable made energy sources. To verify the operating principle boost cascaded buck converter is chosen. The solar inverter is a critical component in a solar energy system. It performs the conversion of the variable DC output of the Photovoltaic (PV) module(s) into a clean sinusoidal 50 or 60 Hz AC current that is then applied directly to the commercial electrical grid or to a local, off-grid electrical network. Typically, communications capability is included so users can monitor the inverter and report on power and operating conditions, provide firmware updates and control the inverter grid connection. At the heart of the inverter is a real-time microcontroller. The controller executes the very precise algorithms required to invert the DC voltage generated by the solar module into AC. This controller is programmed to perform the control loops necessary for all the power management functions necessary including DC/DC and DC/AC. The controller also maximizes the power output from the PV through complex algorithms called maximum power point tracking (MPPT). The PV maximum output power is dependent on the operating conditions and varies from moment to moment due to temperature, shading, soiling, cloud cover, and time of day so tracking and adjusting for this maximum power point is a continuous process. So to utilize the obtained energy with maximum efficiency this paper proposes the interleaved inverter technique. Experimental analysis is obtained from prototype and the results are verified using simulation software. The output current and voltage waveforms are analyzed experimentally using the digital oscilloscope. The experimental results are compared with the results obtained from the software analysis using the matlab software. The analyzed inverter can be applied in non renewable energy sources boost stage cascaded buck inverters in renewable energy systems.

Keywords
PV, Converters, Boost, Buck, Matlab-Simulink.

INTRODUCTION

As the power demand is going on increasing day-by-day, it is responsible for our engineers to make it available as per the demand. Many of the power generating plant are using non-renewable sources as their primary source. But these may become extinct at any time and before facing the situation we have to choose an alternative to avoid the power crisis. One of the best alternatives is choosing Non-conventional sources like solar energy, Wind Energy, Tidal energy, Bio-mass energy etc as the primary sources for power generation in power stations. The power from these sources is several times greater than the one, which we are using at the present. Out of these energy sources, the best one which suits for our country is the solar energy.

The power from the sun intercepted by the earth is approximately $1.8 \times 10^{13}$ MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus if we convert this to other forms of energy, it may be one of the most promising of the non-conventional energy resources.

As we know that the tropic of cancer passes midway through the earth, our country is one of hottest country in the world after the continent Africa[1-7]. There are some places in the country where the mercury level raises upto 50ºc during summer. So, if we use this energy as the primary source for generation almost every house in our country can have power supply and is available at very reasonable cost.

Photovoltaic Cell

Photovoltaic is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity as shown in fig 1.
Working Principle:

Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a photovoltaic cell, they may be reflected, pass right through, or be absorbed as shown in fig 1.2.2. Only the absorbed photons provide energy to generate electricity. When enough sunlight (energy) is absorbed by the material (a semiconductor), electrons are dislodged from the material's atoms.

Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to free electrons, so the electrons naturally migrate to the surface[15-20].

When the electrons leave their position, holes are formed. When many electrons, each carrying a negative charge, travel toward the front surface of the cell, the resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When the two surfaces are connected through an external load, electricity flows[21-24].

Solar Power Inverter

The solar inverter is a critical component in a solar energy system. It performs the conversion of the variable DC output of the Photovoltaic (PV) module(s) into a clean sinusoidal 50 or 60 Hz AC current that is then applied directly to the commercial electrical grid or to a local, off-grid electrical network. Typically, communications capability is included so users can monitor the inverter and report on power and operating conditions, provide firmware updates and control the inverter grid connection. Depending on the grid infrastructure wired (RS-485, CAN, Power Line Communication, Ethernet) or wireless (Bluetooth, ZigBee/IEEE802.15.4, 6lowWPAN) networking options can be used.

At the heart of the inverter is a real-time microcontroller[8-14]. The controller executes the very precise algorithms required to invert the DC voltage generated by the solar module into AC. This controller is programmed to perform the control loops necessary for all the power management functions necessary including DC/DC and DC/AC. The controller also maximizes the power output from the PV through complex algorithms called maximum power point tracking (MPPT).

The PV maximum output power is dependent on the operating conditions and varies from moment to moment due to temperature, shading, soiling, cloud cover, and time of day so tracking and adjusting for this maximum power point is a continuous process. For systems with battery energy storage, the controller can control the charging as well as switch over to battery power once the sun sets or cloud cover reduces the PV output power as shown in fig 3.

The controller contains advanced peripherals like high precision PWM outputs and ADCs for implementing control loops. The ADC measures variables, such as the PV output voltage and current, and then adjusts the DC/DC or DC/AC converter by changing the PWM duty cycle.

Solar light system can be used where we face the problem of electricity or load scheduling. It can be used for home light system, common light for apartments, for garden light, emergency light etc. And solar water heaters are ideally suitable for all types of applications where hot water is required.
The present modes of water heating insure the heavy recurring expenditure for conventional fuel like electricity, kerosene, wood, diesel etc. It is appropriate in accordance with the government policy to use energy saving devices, which will save your recurring expenses and will also save the conventional energy. In the capital city of India, Delhi, citizens can face hours without electricity, but they are the lucky ones. In some parts of India it can be days. The basic weakness of the electric supply industry is non-viability of tariff. In 2001-02, the cost of supply was Rs.3.50 a unit while the realization was only Rs.2.40. Free or highly subsidized supply for agriculture and subsidies to domestic consumers have resulted in uneconomic charges for industrial consumers. This policy has driven many industries to depend more and more on self-generation.

A second weakness of the Indian situation is under investment in transmission and distribution relative to generation[30]. This is due to the lack of proper return in the investment of the power stations. This leads to the increase in price/unit and making the cost unreasonable for the common man.

The use of solar energy for the production of electricity reduces the price/unit as low as 50 paise. The only problem in this procedure is the high installation charges. So, if our engineers work in such a way so as to reduce that cost and in further developments of the equipment, we can definitely meet the power demand in the future and this will be an ENERGY SOLUTION.

**DC-DC CONVERTER**

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. In addition, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc. This is a summary of some of the popular DC-to-DC converter topologies[31].

**Existing Method**

With continuous conduction for the Buck-Boost converter \( V_o = V_{in} \) when the transistor is ON and \( V_o = V_{in} \) when the transistor is OFF. For zero net current change over a period the average voltage across the inductor as shown in fig.4

\[
\frac{V_{in}t_{on}}{t} + \frac{V_{o}t_{off}}{t} = 0
\]

which gives the voltage ratio

\[
\frac{V_o}{V_{in}} = \frac{D}{1-D}
\]

and the corresponding current

\[
\frac{I_o}{I_{in}} = \frac{(1-D)}{D}
\]

Since the duty ratio “D” is between 0 and 1 the output voltage can vary between lower or higher than the input voltage in magnitude. The negative sign indicates a reversal of sense of the output voltage. The main drawbacks are High switching loss, High inductor size, High input filter value.
Proposed Methodology

Interleaving technique was proposed long time ago. In the last years, some applications make use of this technique to improve the performance of the dc-dc conversion. Dynamic response of VRMs is improved with it; also, automotive systems use it to reduce the size of input and output capacitors; and other applications take advantage of this technique to improve a particular characteristic[32]. Most of the published papers regarding multiphase converters include a current loop in each phase to achieve two objectives:

(a) Improve dynamic response: by using a current mode control, a higher bandwidth can be achieved.

(b) Balance the phase currents: dc currents differences are restored by the control.

The main advantage of this system is Reduced inductor size and switching loss, High efficiency.

Modes of operation

Mode 1
1. When mode 1 the switches M6,M7 are on the energy will store in the inductance L,L1 and the Switches M1,M4 are ON.
2. The current path is flow in positive direction

Mode 2
1. When mode 2 the switches M2,M3 are on the energy will store in the inductance L,L1,L2 and the Diode2 act as a forward bias.

SIMULATION RESULTS

Fig 5  Circuit diagram of the proposed PV inverter (Buckmode)

Fig 6 Triggering pulse for Boost and Buck modes.
The PV panel acts like a dc source feeding the converter. The boost-buck converter gives a rectified sinusoidal dc output[33-36]. The dc voltage fed as the input to the full bridge inverter in unfolded to a line frequency ac output voltage. The output voltage is then supplied to the load.

### HARDWARE RESULTS

#### HARDWARE PROTOTYPE

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>12 V (Practicals)</th>
<th>12 V (Theoreticals)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>8 V (Prac)</td>
<td>6 V (Theo)</td>
</tr>
</tbody>
</table>

### FORMULAE:

For Buck-Boost Converter, Output Voltage ($V_a$) = ($V_s \times D$) / (1 - $D$)

Where $D$ = Duty Cycle Ratio, $D$ = 0.5 (For this prototype)

For Buck mode: $V_a = V_s \times D$

For Boost mode: $V_a = V_s / (1 - D)$

### BOOST MODE OUTPUT WAVEFORM
**Input Voltage**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boost</td>
<td>12 V (Prac)</td>
</tr>
<tr>
<td></td>
<td>12V(Theo)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mode</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buck</td>
<td>110 V (Prac)</td>
</tr>
<tr>
<td></td>
<td>24 V (Theo)</td>
</tr>
</tbody>
</table>

**Output Voltage**

**CONCLUSION**

The Boost Cascaded Buck Converter based Photovoltaic Inverter has been implemented, simulated and tested with a hardware prototype using an interleaved multiphase structure. Finally, the results indicate that the efficiency of the proposed solution is higher than the conventional solution under the same condition. However it is clear from the above paper that if a maximum power tracking system is implemented, it improves the efficiency of this method further. Maximum power point tracking (MPPT) is a technique that grid-tie inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, through optical power transmission systems can benefit from similar technology.

**REFERENCE**

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**Efficiency**

\[
\text{Efficiency} = \left( \frac{\text{Vth}}{\text{Vpr}} \right) \times 100 \\
= \left( \frac{6}{8} \right) \times 100 \approx 75\% \text{ approx.}
\]
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