A Novel Converter Topology For Photo-Voltaic Application

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Abstract: This paper proposed a simple dc-dc converter for stand-alone photo-voltaic power conversion in order to reduce the complexity in existing system. The proposed converter topology has the simple structure and has the ability to eliminate the higher order harmonics. Also due to the presence of transformer, the efficiency will be more than that of other converters. The control signal for this converter switch is generated by means of maximum power point tracking (P&O) algorithm. The whole system is modeled by using MATLAB/ Simulink model.

Keywords: Boost Converter, Cuk converter, SEPIC, Fly-Back converter, MPPT, P&O

I. INTRODUCTION

Solar is the most promising source for power generation; that is to meet the energy demand it is must to increase the power generation, to achieve this Renewable Energy Sources are the only method of generating power. There is various renewable energy sources like wind, biomass, fuel cell, ocean are used for this purpose. Comparing to all the sources solar power is the only source which is not depleted at any cost. The advantages of using this power are: Pollution free and Available freely in nature.

The solar power conversion is done by two methods: Solar Photo-Voltaic Power Conversion and Solar Thermal Power Generation. Here Photo-Voltaic conversion method only considered. The power from the solar cell is in the form of DC, it is directly connected to the battery for storage or to the DC load directly. The dc-dc converter is used in this part to reduce the ripples and harmonics.

The dc-dc converter converts the constant dc into the variable dc voltage. There are different types of dc-dc converters are available, it is classified based on the output voltage: Step-up / Boost converter, Step-down or Buck converter, Cuk converter, Buck – Boost converter, Fly-back converter. The overall block diagram is shown below:

![Proposed system Block Diagram](image)

II. DC-DC CONVERTERS

Boost converter [3] will step up the input voltage according to the duty cycle value of the switch used. The output voltage can be varied by changing the duty period. Whereas in buck converter [3] output voltage is less than the input voltage (Step down); the output is varied from 0 to the input value. Both the converters are not capable of eliminating the higher order harmonics itself. So that additional filter capacitor is added to do this.

Cuk [5] converter will perform both steps up and step down operation in a single circuit based on the duty cycle value. But the output is in the opposite form of input; that is if input is positive than the output is negative and vice versa. The SEPIC [6] (single ended primary inductor converter) is also fused with the cuk converter to get the more accurate results. Also this will be used as a single converter for this application.

Fly-back [1] converter is used for both ac/dc and dc/dc conversion. The transformer winding used in this is different from the normal transformer winding. That is it does not transfer the energy from primary to secondary simultaneously. The switch is turned on and off by means of control signal from the controller (MPPT) unit.

When the switch is on, energy is stored in the primary winding and while during off time stored energy is transferred to the secondary winding. The capacitor is connected across the load to provide the filtering action and
un-interrupted power to the load. Fig-2 shows the general fly-back converter topology; the practical circuit needs additional snubber circuit and controller to provide the gate pulses to the switch.

![Fly-Back Converter Topology](image)

The transformer design is based on the input and output voltage requirements.

The primary winding current rises from \( I_p \) to \( I_o \) in \( \delta T \) time.

\[
I_p - I_o = \left( \frac{E_{dc}}{L_{pri}} \right) \delta T \tag{1}
\]

Under steady state Energy to the primary winding during each ON transition

\[
E_{dc} \times 0.5 \times (I_p + I_o) \delta T \tag{2}
\]

Output energy in each cycle

\[
V_I_{load} \delta T \tag{3}
\]

\[
E_{dc} \times 0.5 \times (I_p + I_o) \delta T = V_I_{load} \delta T \tag{4}
\]

The mean(dc) voltage across primary and secondary windings must be zero

Switch is ON, primary winding voltage equals input voltage. Switch is OFF, the reflected secondary voltage across the primary winding.

\[
E_{dc} \delta = \left( \frac{N_1}{N_2} \right) V_o (1-\delta) \tag{5}
\]

Required ratings for switch,

\[
V_{switch} = E_{dc} + \left( \frac{N_1}{N_2} \right) V_o \tag{6}
\]

Required ratings for diode,

\[
V_{diode} = V_o + E_{dc} \left( \frac{N_1}{N_2} \right) \tag{7}
\]

III. MAXIMUM POWER POINT TRACKING

The generation of gate pulse is based on the maximum power point tracking algorithm. MPPT is a technique [1], used to track the maximum power from the PV panel at all the time to improve the output voltage. This will not rotate the panel; it just modifies the load line from the normal working point to the maximum power point. The fig-3 given below shows the working of tracking algorithm.

There are various algorithms are used for this purpose. Some of them are: Perturbation and Observation (P&O)[1][5], Constant voltage control method, Hill climbing method[6], Incremental conductance method. From those algorithms P&O is the basic for all other algorithms. In this work P&O is only considered for tracking and gate pulse generation. The flowchart given below shows the steps involved in this algorithm. The duty cycle variation can be as follows,

In voltage source region,

\[
\frac{\partial P_{pv}}{\partial V_{pv}} > 0 \Rightarrow \Delta d = \Delta d \text{ or increment } d \tag{8}
\]

In current Source region,

\[
\frac{\partial P_{pv}}{\partial V_{pv}} < 0 \Rightarrow \Delta d = \Delta d \text{ or decrement } d \tag{9}
\]

At MPP,

\[
\frac{\partial P_{pv}}{\partial V_{pv}} = 0 \Rightarrow \Delta d = \text{ retain } d \tag{10}
\]

As per the above equation if \( \frac{\partial P_{pv}}{\partial V_{pv}} \) is greater than zero \( P_{new} > P_{old} \) the duty cycle is increased \( \Delta d \) as operating region in this case is the constant voltage region.
The solar cell is modeled based on the PV current and voltage rating. The solar radiation can be measured by:

\[ I_m = I_{pv} - I_0 \cdot \exp\left(\frac{V + I_{rs}}{V_T}\right) - 1 \quad (8) \]

\[ I_{pv} = (K_i \Delta t + I_{pv,n}) \frac{G}{G_n} \quad (9) \]

\[ I_0 = I_{sc,n} + (K_i \Delta t) / \exp\left(\frac{(V_{on} + K_i \Delta t)}{V_T}\right) - 1 \]

Where,
- \( I_{pv} \) = Photovoltaic current
- \( I_{pv,n} \) = Light generated current
- \( K_i \) = Current temperature co-efficient
- \( G \) = Actual sun irradiation (W/ms)
- \( G_n \) = Nominal sun irradiation
- \( \Delta t \) = Difference between actual and nominal temperature (T - T_n)
- \( I_D \) = Diode current
- \( A \) = Diode identity factor
- \( V_T \) = Junction thermal voltage = \( K T / q \)
- \( K \) = Boltzman constant = \( 1.38065 \times 10^{-33} \) J/k
- \( q \) = Electron charges = \( 1.607 \times 10^{-19} \) C
- \( T \) = Nominal temperature = 298.5 K

The fly-back converter takes the input from the PV panel and it is given to the primary winding through switch. The switch can be turned on and off by the algorithm. The algorithm compares the power value at present and previous duty period are compared and the duty period is changed accordingly. The fly-back converter can be modeled by using the Matlab as follows:

![Fig-7 Fly-back converter model in MATLAB](image)

The above fig shows the modeling of solar cell in the Matlab Simulink model. The above equations are the building block of this modeling. From this PV – current and Voltage are taken as output. These two parameters are given as input to the MPPT algorithm block and to the input source for dc-dc converter.

![Fig-6 Solar cell modeling in MATLAB](image)

The algorithm will take PV voltage and current as an input parameter and calculates the power from those values. Then that is compared with its previous value and the signal passed to the gate terminal of the switch, it will
be turned on. The time interval is set to the controller to check the values.

V. SIMULATION RESULTS

The voltage and power are taken as the output, both are in dc form. The results are listed below:

![Fig-9 PV Output Voltage](image1)

![Fig-10 PV output Power](image2)

The output from the fly-back converter is depending upon the value of parameters in that circuit, the table below shows the values of different parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV panel output current $I_{pv}$</td>
<td>7.35</td>
</tr>
<tr>
<td>PV panel output voltage $V_{pv}$</td>
<td>27.6V</td>
</tr>
<tr>
<td>PV panel output power $P_{pv}$</td>
<td>202.86W</td>
</tr>
<tr>
<td>Input voltage to the fly-back converter</td>
<td>27.6V</td>
</tr>
<tr>
<td>Output voltage from the fly-back converter</td>
<td>30V</td>
</tr>
</tbody>
</table>

Table-1 Parameters used in simulation

VI. CONCLUSION

The simple dc-dc converter for the solar photovoltaic power conversion is proposed in this work. The proposed fly-back converter is analyzed in detail and the advantages of using this converter are low reactive components and more efficiency. It will provide the more efficient result than the other topologies of dc-dc converter. The fly-back output is compared with the other converter results, which gave the support to this work. The output from the fly-back converter is improved by using the Maximum Power Point Tracking (P&O) algorithm. This will assist the converter circuit to give the constant/maximum output at all the times.

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