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Comparison of Single Stage and Two Stage Operation of Solar System

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Abstract- **Generating electrical power from solar energy is very popular. There are many studies aiming at increasing the efficiency and designing simpler systems. Electrical power generated by PV cells depends on solar irradiances, ambient temperatures and electrical loads. Renewable energy sources are a replacement of conventional sources to overcome the environmental pollution issues, raising prices and limited stock. Solar energy is the best alternative to provide abundant and clean source of energy. In order to integrate the solar cell with grid, there are two methods such as single-stage operation and two- stage operation. The major work has been carried out in designing such systems are as follows: 1) extraction of maximum power; 2) DC to AC conversion; and 3) to boost up voltage level. This paper is focused on application of the different types of converters and inverters employed for DC-AC power conversion to make the output of PV as per the requirement of grid.**

Index Terms- **buck-boost inverter , THD.**

1. INTRODUCTION

Demand for energy is increasing every day. Finding new energy sources are always important. Among them, renewable ones, such as wind and solar power, are popular and they are environmental friendly energy sources [1], [2]. For some locations which receive enough solar irradiance, PV panels can be preferred for generating electrical power With rise in population, demand of energy rises exponentially. With limited availability of conventional energy sources, shift focus to the renewable energy sources such as solar energy, wind energy etc. Solar energy is one of the most promising and best ecofriendly energy sources among those renewable energy systems. Photovoltaic cells (PV) are employed to transform solar energy into the electrical energy. The energy obtained from PV cells can be used locally or it can be exported to the grid. However the availability of solar energy depends on weather conditions and the time of usage. Power from PV cells is also highly sensitive to the shading phenomenon. Due to this intermittent nature of source, supplies from PV cells are variable in nature and must be conditioned as per the demand of load or grid specification. This can be done in two ways: (1) single stage operation (2) two stage operation. In this paper the converters used to boost up the DC such as Boost, Ćuk and Sepic converter are discussed and their merits and demerits are compared. Boost converters are DC to DC converters that boost up the output voltage from its input voltage by employing switched mode power supply (SMPS) technique. Ćuk converter has advantage over boost converter as it can provide step up as well as step down voltage from its input voltage. For this, Cuk converter consists of boost converter followed by buck with a capacitor to couple them. Sepic converter is a DC-DC converter which provide output voltage step up, step down as well as equal to the input voltage. Sepic converter provides three dimensions of voltage, more than any other converter (Cuk or boost)

To convert DC supplied by PV cells into AC, the PV cells are connected in series which cause serious problems. These problems are solved by the use of solar –Micro inverters or just micro inverter. They are small inverters designed to handle the output of a single panel.

2. OPERATION OF PV CELLS

The power generated by PV cell supplied to load or grid by either single stage or two stage operation discussed below:

2. 1. Single-Stage operation:

In single stage operation, the DC supplied by the solar cell is directly converted into AC by employing inverters.Schematic representation of single stage PV cell operation is shown here.

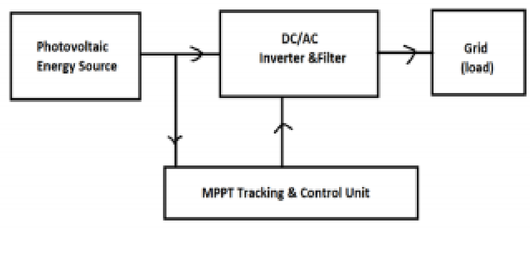

Fig.1 Block Diagram of Single Stage Operation

2.2 Two- Stage Operation

Under two stage operation, firstly the DC output of PV cell is boost up by employing DC-DC converters and then this step up DC is inverted into AC as per the demand of grid by using inverters. Schematic representation of two stage operation of PV cell are shown below.

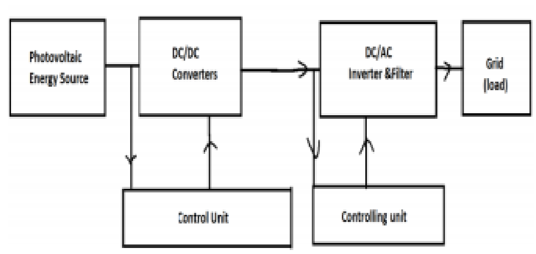

Fig.2 Block Diagram of Two-Stage Operation

3. Elements Used

3.1 INVERTERS

The power supplied by solar cell is DC. However our home appliances as well as grid works on specific AC voltage and frequency hence require inversion and conditioning of this DC power. This can be done by inverters. Inverters are circuits use to invert DC power into AC at desired output voltage and frequency. Inverters are basic circuits used in both stages of PV system (single as well as two stage of operation).

3.1.1 Half Bridge Inverter.

Half bridge inverters are used to invert the DC input voltage. The amplitude of the output is half the input.[1][10][11] output AC voltage of half bridge inverter is given by formula:

$V_{ac} = V/2$ ……… (1)

Where V is the DC supply voltage .The circuit of half bridge is shown below:

The problem with the half bridge is its low output magnitude and its requirement of 3 wire DC supply system. However this problem is overcome by full bridge inverter.

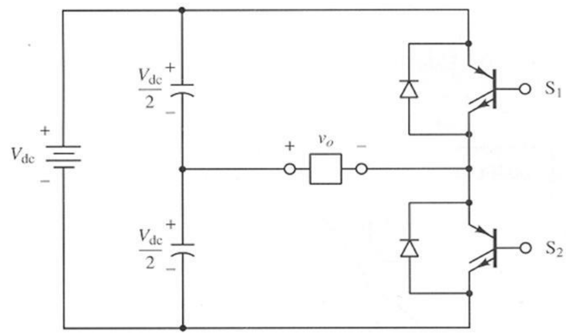

Fig 3. Circuit Diagram of Half Bridge Inverter.

3.1.2 Full Bridge Inverter.

It consist of four Thyristors and four Diodes to invert the supplied DC voltage. Though the number of thyristors and diodes are doubled as compare to the half bridge but the output of full bridge is also double. Given by the formula:

$V_{ac} = V_{dc}$ ……….. (2)

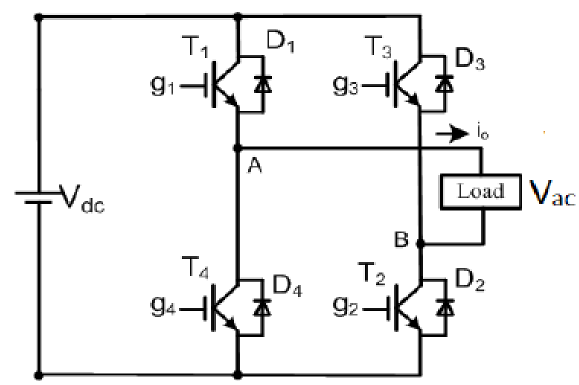

Fig.4 Full bridge Inverter

3.1.3 Multilevel Inverter

In the recent years, inventers and manufacturers shift their interest towards multilevel inverters because of its advantages over conventional full bridge inverter. The use of multilevel inverter improves the output waveforms, reduce the size of filter, have lower EMI and lower the total harmonic distortion (THD). The harmonic contents present in the output voltage are determined by the carrier frequency and switching functions. Harmonic content can be reduced by increasing the output levels. This can be done by employing five level inverter is discussed in this paper. The circuit diagram is shown below

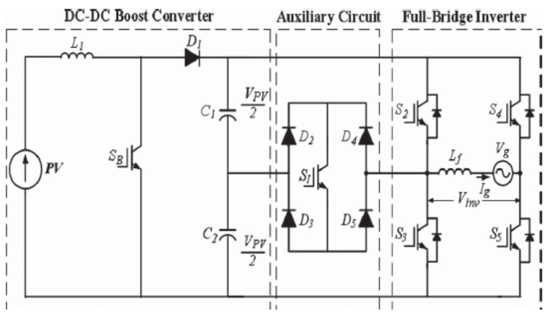

Fig .5 Single Phase Five Level Inverter Topology

3.2 CONVERTER

3.2.1 Boost Converter

As name suggests Boost converters are employed to boost up the DC output of PV cell. Boost converters generate output voltage always greater than the input voltage. A typical boost converter circuit is shown below in figure 6.

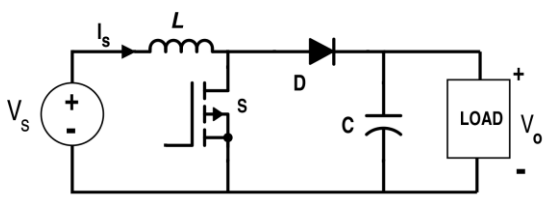

Fig.6 Boost Converter

step up voltage given by formula:

$V_0 = Vi/ 1{-}D$……. (3)

The main feature of boost converter is its high efficiency as it is a single power device. Also the boosting of voltage can be easily controlled by adjusting the duty cycle. However the output voltage is quiet sensitive to change in duty cycle , hence difficult to stabilize. Boost converter require large size of L and C as large RMS current flow through filter capacitor.

3.2.1 Cuk Converter

The Ćuk converter dominates the boost converter by its ability to provide step up as well as step down voltage from its input voltage. Hence provide more control. Cuk is a capacitive energy fly back converter. It uses Capacitor to store and transfer energy in place of inductor used by boost converter. Schematic representation of Cuk convereter are shown in Figure 7.

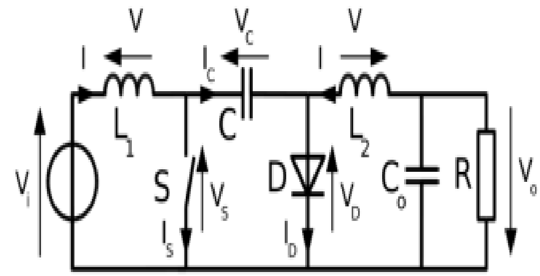

Fig.7 The Cuk Converter

Output voltage of the Cuk is given by formula:

$V_0 = -DV_i\ /1{-}D$ ……. (4)

The unique feature of Cuk, it has both input and output current non pulsating in nature. It is possible to eliminates ripple current in the circuit and thus have low requirement external filtering circuit. The Cuk face a problem of inverted output. The voltage output of Cuk is of opposite polarity as per the input apply. This problem leads to the birth of SEPIC converter

3.2.3 SEPIC Converter

It is a DC-DC converter which dominates the other members of converter family by the fact that, it can provide greater than, less than or even equal to the input voltage. From design point of view it is a boost converter followed by the buck boost converter, helps to generate non inverted output. The output voltage of SEPIC have same polarity as input. This can be represented by the formula:

$V_0 = D\ V_i/\ 1{-}D$ …… (5)

Where D is the duty cycle, Vi is the input voltage. The circuit diagram of SEPIC are shown below:

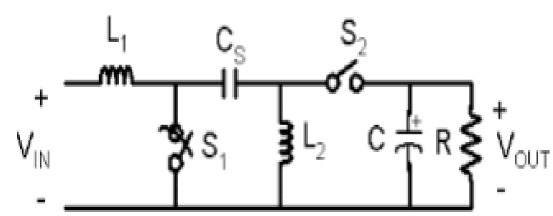

Fig.8 SEPIC Converter

SEPIC converter suffers from the problem of pulsating output current as in case of buck –boost converter. SEPIC converters are quiet difficult to control because of their fourth order nature hence suitable for slowly varying application.

4. COMPARISON TABLE

Parameters	Single Stage Operation	Two Stage Operation
Efficiency	low	High
THD	high	low
Output Voltage	high	low
Complexity	less	more

5. CONCLUSION

This paper review the single stage and two stage operation of solar power energy system along with various converters and inverters employed in both the stages. The merits and demerits of converters and inverters are discussed along with their circuit used in the operation. Two stage operation are proved to have high efficiency in conditioning the output of PV cell, though require high investment and have complex structure.

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