

ANALYSIS AND DESIGN OF SOFT SWITCHING BASED INTERLEAVED FLYBACK CONVERTER FOR PHOTOVOLTAIC APPLICATIONS

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Abstract - This paper presents analysis and design of soft switching based interleaved flyback converter operating in discontinuous current mode for photovoltaic (PV) applications. The switching loss is reduced by operating the switch based on zero voltage switching technique where switching takes place when the voltage attains zero. Due to this power loss get reduced and efficiency of the system get improved. To obtain maximum power from PV panel, the Perturb & Observe (P&O) algorithm is used. The simulation of flyback converter is performed by using MATLAB/Simulink platform and the efficiency, total harmonic distortion, power factor are measured as 99.17%, 3.69% and 0.93.

Keywords - Flyback converter, soft switching, photovoltaic (PV), discontinuous current mode (DCM), perturb & observe algorithm (P&O).

I. INTRODUCTION

Nowadays solar power play a major role in electricity generation because prime source of solar power is sun light and free of cost. And in our electricity market amount of energy resources is low when compare to actual demand, to overcome the demand renewable energy is used so that the research is based on solar power. The usage of this technology is reduced due to it high cost. The main objective of this paper is to use the flyback topology for photovoltaic applications with low switching losses.

The structure of flyback converter is simple and it is easy to control the power flowing through it. The flyback converter is cheap and it requires lower number of elements compared to other converters available in the market. This is due to the fact that the inductor is combined along with the transformer. But in other converters, the inductor and transformer are separate elements. As we know

that the inductor is an energy storage element and the transformer is used for transfer of energy from one system to another without changes in frequency. Since these two elements are present in the flyback converter itself, the size and cost of the converter get reduced. The major objective is to use flyback converter topology more effectively to reduce the cost associated with photovoltaic applications.

Implementation of transformer with high energy storage is always a difficult task. For high energy storage, the air gap between the windings of transformer is quite large and due to this the magnetizing inductance of the windings is very small. Achieving a transformer with small magnetizing inductance with low leakage inductance is always a challenge. A flyback converter built with a transformer that has large leakage flux and poor coupling will have poor energy transfer efficiency. Due to this reason, the flyback converter is not suitable for high power applications. As a result, the flyback topology play a limited role in PV applications only at very low power as micro inverter. The flyback converters are interleaved to make it suitable for high power applications. Another benefit of interleaving is that the frequency of ripple components is increased in proportion to number of cells which allows easy filtering.

In the existing system (flyback converter without soft switching), the switch face large peak current stress which results in high switching loss. In order to reduce the switching loss, the new system is

proposed in which the switching loss is reduced by using zero voltage switching technique [1].

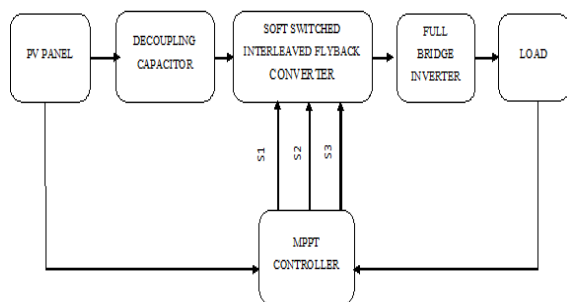


Fig1: Block diagram of soft switching based interleaved flyback converter

Fig1 shows the Block diagram of soft switching based interleaved flyback converter. The operation mode of converter is discontinuous current mode (DCM). The major reason for selecting DCM operation is that it provides fast dynamic response, reverse recovery problem is absent, and size of the transformer is small and easy to control. Along with these advantages, it has some disadvantages also. The form factor of output current in discontinuous current mode is high which leads to more power losses. In DCM operation, the switch will face large peak current stress and high voltage stress during turn off which results in high switching loss. It leads to more power losses and it is overcome by soft switching. The soft switching based flyback converter overcome the drawbacks of discontinuous current mode operation.

II. FLYBACK CONVERTER OPERATION

As shown in Fig2, the PV panel is connected to a three cell interleaved flyback converter via a decoupling capacitor. The flyback converter has a MOSFET with diode in series and capacitor in parallel at the primary side. The diode is at the secondary side. The topology also has a full bridge inverter and low pass filter. When the MOSFET switches (S1,S2 ,S3) are turned ON, the current start flows from the PV panel in to the flyback transformers magnetizing inductance and energy is stored in the form of magnetizing inductance. During the on time of the switches, the secondary

side diodes are reverse biased due to the polarity of charges in the transformer windings.

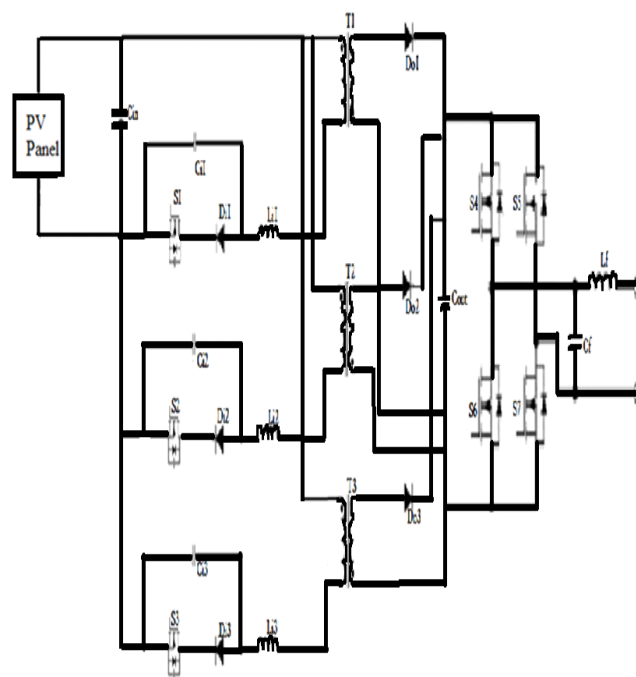


Fig2: Circuit diagram of soft switching based interleaved flyback converter

When the flyback switches are turned OFF, the energy stored in the magnetizing inductance is transferred to the full bridge inverter in the form of current. During the MOSFET switch OFF time, the L-C tank circuit resonates. Due to this the voltage across the switch changes from zero to its peak value and again it comes to zero. Therefore lossless zero voltage transition occur at this point. Since the device capacitance of the MOSFET switch has been discharged by the resonant tank, it does not introduce power loss or dissipation in the switch. Therefore, the MOSFET transition losses goes to zero irrespective of operating frequency and input voltage. This will save the power and improve the overall efficiency of the system.

The output of the flyback converter is applied to the full bridge inverter. The full bridge inverter is used for converting the dc into ac. The sinusoidal pulse width modulation technique is used to generate firing pulses for the inverter switches. Generally, the source from the PV panel is not an ideal one and it will leads to variations in terminal

voltages. In order to avoid this, the decoupling capacitor is placed at the input of flyback converter and it bypass both low and high frequency ac components and it allows only dc component to be supplied by the PV panel. The inverter use insulated gate bipolar transistor (IGBT) switches and the low pass filter is responsible for removing the high frequency harmonics at the output waveforms.

III. DECOUPLING CAPACITOR SELECTION

The quality of the output waveform is mainly dependent on the quality of the dc voltage at the flyback converter input, which is also the voltage at the PV terminals. The ripple content in the PV voltage cause utilization losses at the PV power. So ripple at the PV voltage is made as low as possible to utilize the solar power more efficiently. The decoupling capacitor acts as a buffer and it provides power balancing between the PV panel and the output. So the decoupling capacitor is sized in such a way that it should divert the double line frequency component in the PV source by creating a low impedance path to maintain a low ripple at the PV terminal voltage [2].

IV. MAXIMUM POWER POINT TRACKING

The relationship between current and voltage varies throughout the day due to temperature and irradiation. There is only one operating point where maximum power is extracted which is called maximum power point (MPP). In order to locate the MPP, maximum power point tracking algorithms are used [3][4]. The Perturb & Observe algorithms is frequently used because of its simplicity. In this algorithm by perturbing the duty ratio of flyback converter, the DC link voltage and current between the PV panel and the flyback converter is adjusted to obtain maximum power. The flow chart of P&O algorithm is shown in Fig3. From the measured value of PV voltage and current, the power of the PV panel is calculated. The change in voltage is obtained by finding the difference between the present and previous voltage. Similarly the change in PV power is calculated. If the change in power and voltage is positive then the duty ratio is

decremented. If the change in power is positive but change in voltage is negative then the duty ratio is incremented. The required duty ratio is obtained by MPPT algorithm and the firing pulses for flyback converter is generated.

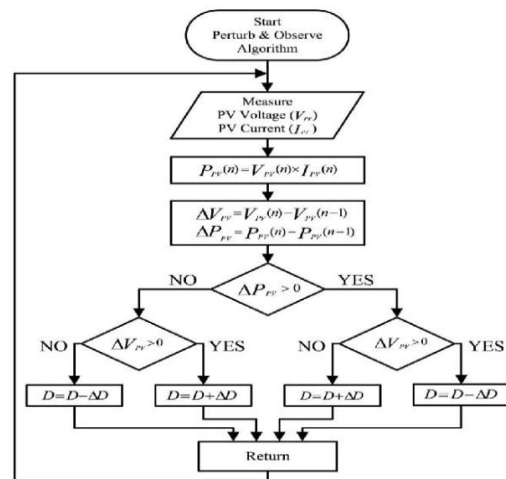


Fig3: Flow chart of P&O method

V. SOFT SWITCHING TECHNIQUE

Soft switching can diminish or reduce some of the mechanisms of switching loss and may reduce the generation of EMI. If semiconductor devices are switched on or off at the zero crossing of their voltage or current waveforms. It eliminate overlap between voltage and current and thus minimizing losses. The two techniques in soft switching are zero current switching and zero voltage switching. In Zero Current switching (ZCS), turn-off transition occurs at zero current. It eliminates the switching loss caused by switch current tailing and by stray inductances.

In Zero Voltage Switching (ZVS), turn-on transition occurs at zero voltage [5][6][7]. Diodes may be also operate with zero-voltage switching. This will eliminates the switching loss induced by diode stored charge and device internal capacitances. It is usually preferred in modern converters. Zero-voltage transition converters are modified into PWM converters, in which an inductor charges and discharges the device it may be capacitances. The major advantages of ZVS is that ,the MOSFET transition losses are zero

regardless of operating frequency and input voltage representing a noteworthy savings of power and substantial improvement in efficiency. Such attribute make ZVS a good technique for high frequency, high voltage converter designs. It reduces the harmonic spectrum of any EMI and allows higher frequency operation resulting in reduced, easy to filter noise and the use of smaller filter components. Due to these advantages, the ZVS is employed in the flyback converter.

High-quality (PV) modules are subject to a number of requirements as we need. First, they have to deliver the rated power, should be reliable and withstanding the environmental conditions. They must also be safe and long-lasting, ensuring the system's high yield over the long term [8]. And, they should also able to generate the full amount of energy in the shortest possible time. For a given irradiation of about 2030, the voltage and current obtained from PV panel is 88V and 22A.

VI. PHOTOVOLTAIC MODULE

VII. SIMULATION RESULTS

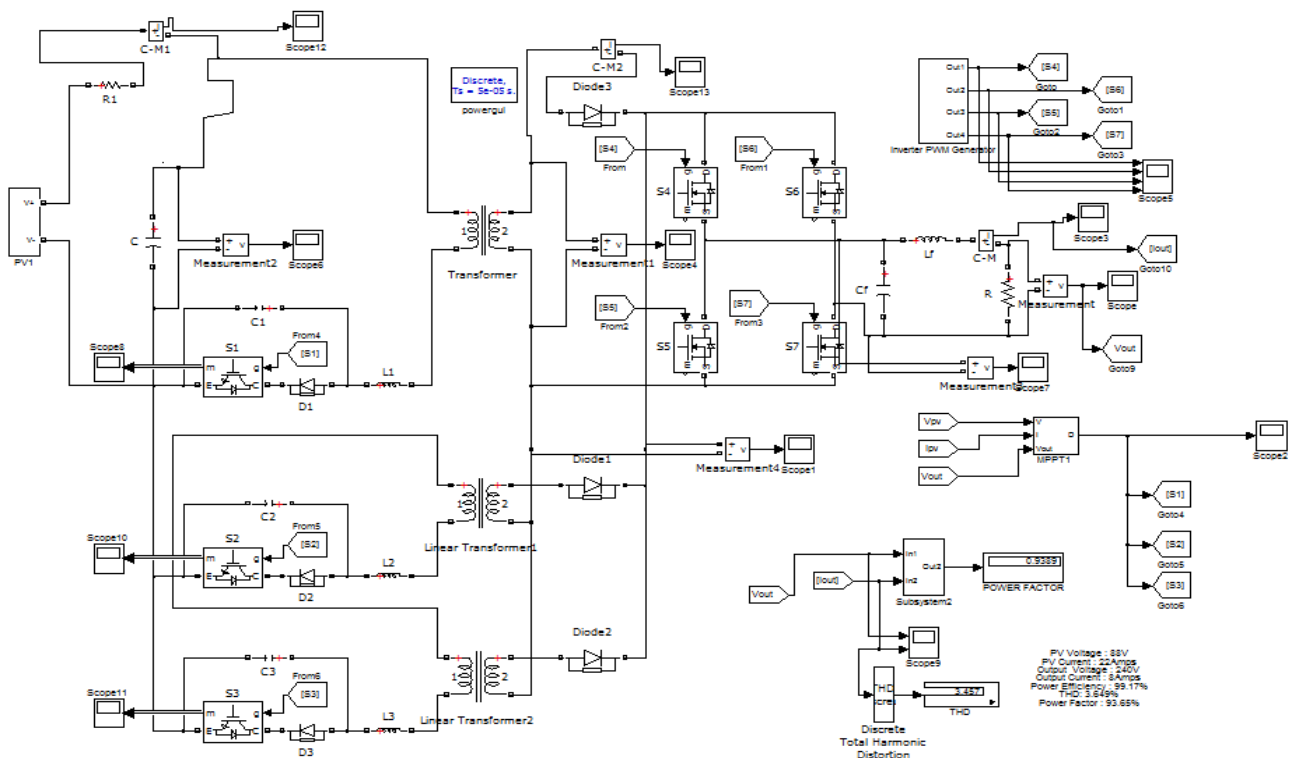


Fig4. Simulation diagram of soft switching based interleaved flyback converter

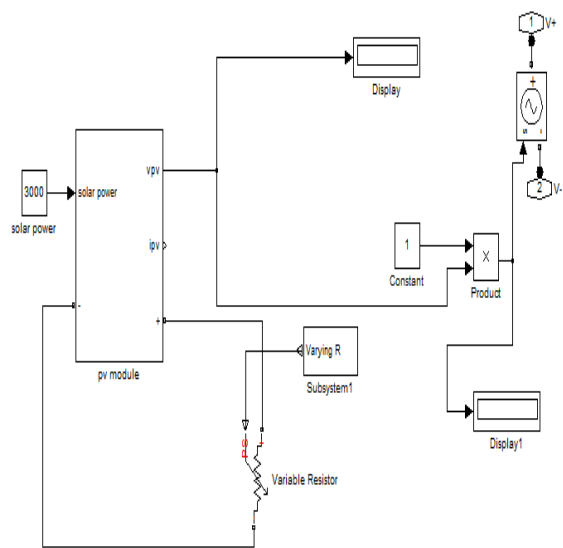


Fig5: PV panel design

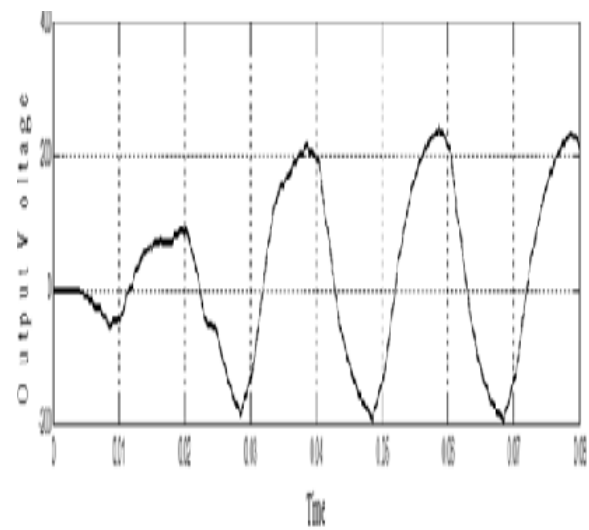


Fig7: Output voltage of flyback converter without soft switching

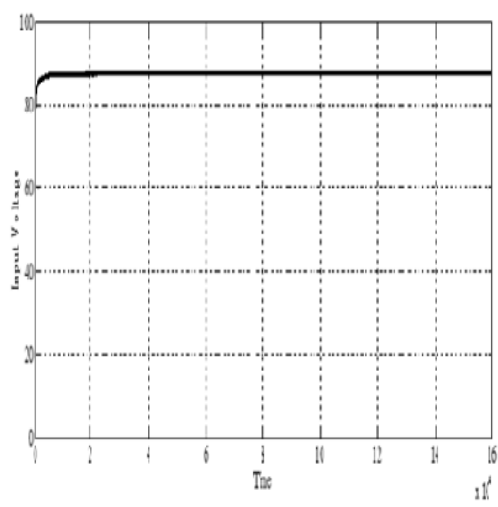


Fig6: Input voltage

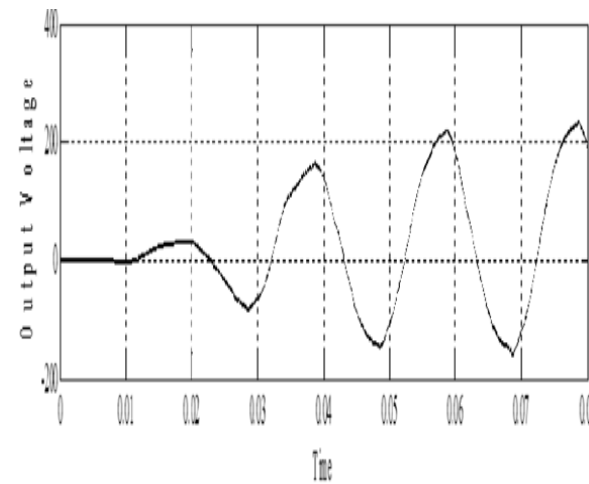


Fig8: Output Voltage of flyback converter with soft switching

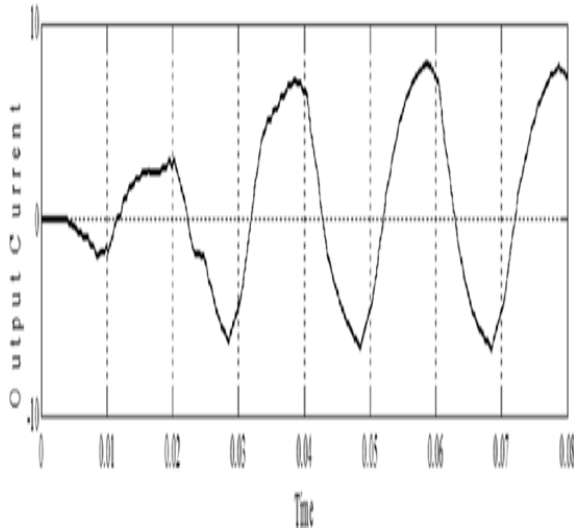


Fig9: Output current of flyback converter without soft switching

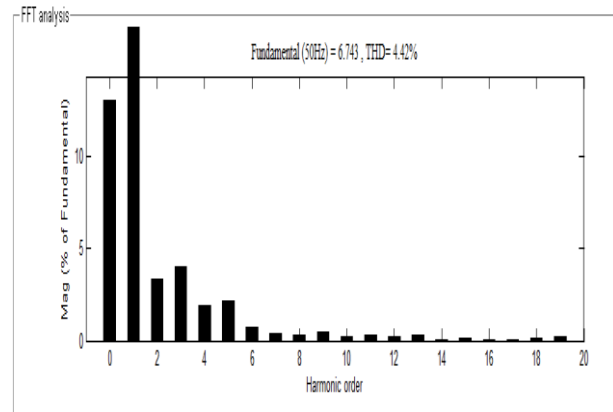


Fig11: THD analysis of flyback converter without soft switching

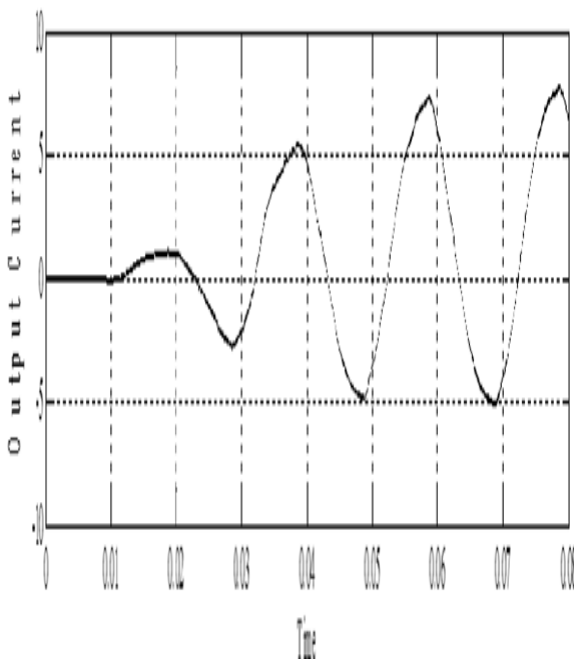


Fig10: Output current of flyback converter with soft switching

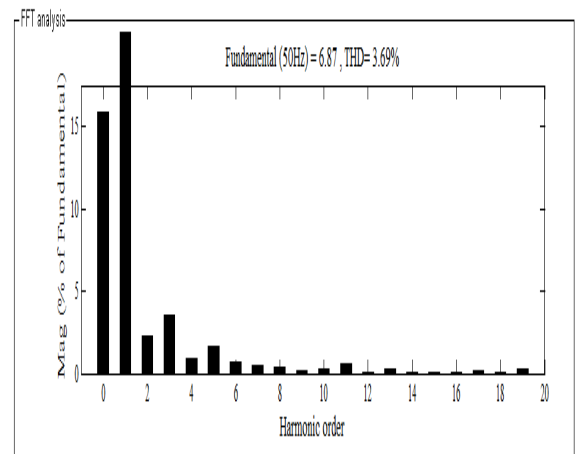


Fig12: THD analysis of flyback converter with soft switching

This analysis is performed by Fast Fourier Transform (FFT). In this proposed system THD is somewhat reduced, nearly 3.69 it is shown in Fig12.

VIII. CONCLUSION

The three cell interleaved flyback converter with Zero Voltage Switching (ZVS) technique is used for high power applications. The flyback topology is selected because of its simple structure and easy power flow control with high power quality outputs. The simulation results prove the successful operation of the converter. The performance parameters of the proposed converter and the existing converter have been

investigated and it is found that the proposed converter gives a output current with a THD of 3.69%, the efficiency 99.17% and a power factor of 0.93. Compare to that, the existing converter has a output current with THD of 4.42%, the efficiency of 90.17% and a power factor of 0.94.

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