

# Grid-Tied Interleaved Flyback Inverter for Photo Voltaic Application

Abitha M K<sup>1</sup>, Anitha P<sup>2</sup>

P.G. Student, Department of Electrical and Electronics Engineering, NSS Engineering College Palakkad, Kerala, India<sup>1</sup>

Professor, Department of Electrical and Electronics Engineering, NSS Engineering College Palakkad, Kerala, India<sup>2</sup>

**ABSTRACT:** This paper focus on a special type of inverter topology for photo voltaic applications. The proposed system is a grid connected inverter system based on interleaved flyback topology. Aim of this paper is to design flyback inverter at high power because today's PV inverter technology based on this topology only used at very low power as micro inverter. The analysis of proposed flyback inverter and the source of proposed system i.e. photo voltaic array are simulated in MATLAB 2013a software. To track maximum power, the maximum power point tracking (MPPT) method is used and it is modelled using Perturb and Observe (P&O) algorithm. The paper also concerned with the design method as well as operation of flyback inverter with interleaved winding.

**KEYWORDS:** Flyback, Interleaving, Maximum power point tracking (MPPT), Photo voltaic.

## I. INTRODUCTION

Nowadays the benefits of power generation from renewable energy sources, such as Photo voltaic (PV) or Wind power system are widely accepted because they are environmentally friendly and inexhaustible. In last year's, global warming and energy policies had become main topic on international agenda [1]. The emissions due to PV power generations are only from the production of its components. They will produce electricity from the solar irradiance without the emission of green house gases. The solar energy has been one of the most interesting research areas in the past decades, both for grid-connected and stand-alone applications.

The grid-connected inverter topologies have important role in the exponential growth of cumulative PV capacity. The PV array is connected to the AC grid through a common DC/AC converter. The switching of full bridge gives the appropriate sequence of AC output voltage. Interfacing of power converter is major requirement between the PV array and the grid because they play two major tasks [2]-[5]. First job is to inject a sinusoidal current in to the grid and second job is to reduce harmonic content in the grid injected current and voltage. Here the power converters are normally two type, one is DC-DC converter that is used to operate at maximum power point. The second one is DC-AC power converter used to interconnect the photo voltaic system to the grid.

Flyback converters are most commonly used SMPS circuit for low power applications. The overall circuit topologies of flyback converters are simpler than other SMPS circuits, also the topology easy for power control. The ability of flyback topology is that combining of energy storage inductor with the transformer. This is the main difference of flyback topology from other topologies because they are two separate components in others, so this topology is a low cost converter. Here we try to achieve a high-power by implementing flyback converter with good performance, which is the primary research contribution also try to conserve the cost advantage [4]-[7]. A flyback converter combining with transformer has large leakage flux and poor coupling, which will lead to poor energy transfer efficiency. This is the reason for designing of flyback converter at low power as micro inverters. As a result, this topology has limited role in the PV applications. The interleaving of high-power flyback cells easily yielded to develop a central type PV inverter. Interleaving also gives added benefit such as reducing undesired harmonics i.e. increasing ripple component at the wave form easy for filter out using smaller sized filtering element.

The selection of operation mode for the converter is discontinuous current mode (DCM) this is optimal control method because of its fast dynamic response, no reverse recovery problem, elimination of electromagnetic interference and losses. The proper interleaving reduces the contrary effect of the DCM operation such as high RMS to mean ratio. This higher form factor of current wave form leads to more power losses. Another drawback is current pulses with large

peaks; these can overcome by interleaving of several cells [8]-[14]. The maximum harvesting of solar energy is achieved using maximum power point tracking method, here the method is perturb and observe. It is the most widely used algorithm due to its simple structure and lesser required parameters. These studies have developed and presented the grid-tied interleaved flyback inverter as a central type PV inverter designed at 2KW. The study has developed three high power flyback transformers at 700W with low leakage inductance.

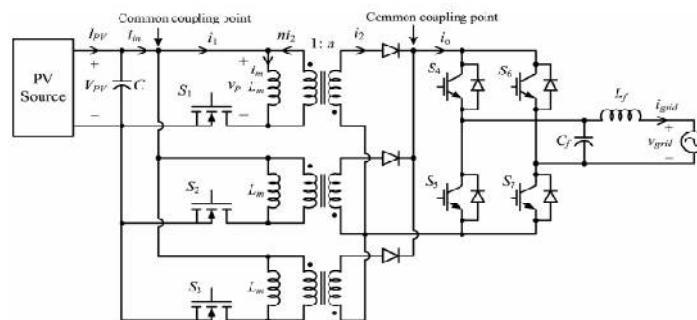


Fig. 1. Proposed three cell interleaved flyback converter topology

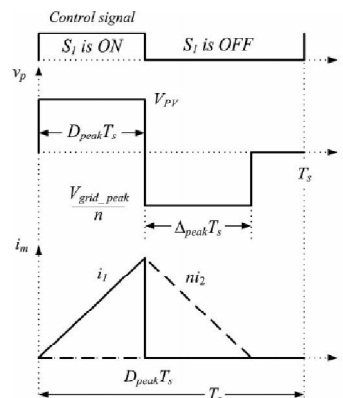


Fig. 2. Control signal for flyback switch, flyback transformer primary voltage ( $v_p$ ), magnetizing current ( $i_m$ )

## II. PROPOSED SYSTEM CONFIGURATION AND ANALYSIS

There are three parts in PV ac module system. The first one is PV module that generates power between 1.5 and 2KW. The second one is the power conditioner that is to convert dc power to ac power. Then the third one is grid line that generates 50 Hz voltage and current.

### A. System structure and operation

Fig. 1 shows the circuit schematic of proposed system. It consist of a decoupling capacitor, flyback converter, H-bridge inverter, low pass filter, MPPT controller and grid synchronized signal generator. The decoupling capacitor is used to eliminate harmonics in panel output [7]. To generate peak power it is essential to have a maximum power point tracker (MPPT). The constant voltage and current is required to control MPPT [9]. The flyback converter consist of main switches i.e. Metal-oxide semiconductor field effect transistor (MOSFET) for switching primary side, diodes and transformers. The transformers are used to maintain isolation between the PV module and grid line and also to boost the voltage. The interleaved flyback converter is supplied by PV source through a decoupling capacitor. When the main MOSFET switches are turned ON, current start to flow from PV source to flyback transformer's magnetizing inductance [10]-[13]. The energy stored at that time as a magnetic field. At the ON time of main switches,

there is NO current flow through secondary because of the diodes. When switches are OFF, diodes become forward biased and current is supplied to grid. There is H-bridge inverter just to unfold the sinusoidally modulated dc current packs into ac. The switches of full bridge inverter operated at grid frequency and IGBT used as full ridge inverter switch. Low pass filter provided at output side to reduce total harmonic distortion.

### B. Converter analysis

For designing of proposed system it is important to analyse flyback converter. Particular switching period is taken for analysis at that period grid voltage and duty ratios are at peak values. Fig. 2 shows the control signal, flyback transformer primary voltage and magnetizing current. Here the wave form represents DCM operation [5]-[7]. When flyback switch is turned ON, current  $I_{PV}$  from PV source delivered. So the relationship between flyback converter parameters and PV source output power can be written as follow;

$$P_{PV} = V_{PV} I_{PV} = \frac{n_{cell} V_{PV}^2 D_{peak}^2}{4L_m f_s} \quad (1)$$

TABLE I  
DESIGN SPECIFICATIONS

Design parameters	Specifications
PV model and maximum power	BP365, 65 W
Open circuit voltage and short circuit current per panel	21.7 V, 3.99 A
PV panel group arrangement	5 panels in a string and 6 strings in parallel
Voltage and current at the maximum power point per panel and per the selected panel group arrangement	17.6 V, 3.6932 A 88 V, 22.16 A
Total maximum dc power from the panel group	1950 w
MPPT energy harvesting efficiency	>98%
Grid characteristics	Single-phase, 220 V, 50 Hz 143–264 V RMS 45.5–54.5 Hz
Switching frequency	40 kHz
Number of interleaved cells	3

Using this equation, the magnetizing inductance ( $L_m$ ) can be calculated. Here the  $n_{cell}$  is the number of the interleaved cells,  $f_s$  is the switching frequency and  $D_{peak}$  is the peak duty ratio. When switch is turned OFF, the average power drawn from PV panel equal to the active power transferred to the grid.

$$P_{PV} = V_{PV} I_{PV} = \frac{n_{cell} V_{PV}^2 D_{peak}^2}{4L_m f_s} = \frac{\sqrt{V_{grid}} I_{grid}}{2} = P_{grid} \quad (2)$$

### III. DESIGN OF PROPOSED SYSTEM

The major designing parts are power converter part and control part. The overall system is designed for 2KW and switching frequency selected as 40 KHz in order to achieve high efficiency. The choice of switching device should

have fast current fall time ( $t_f$ ) to reduce the turn-off losses, So we use MOSFET as the flyback switch. The MOSFETs with low voltage ratings have much lower on-state resistance ( $R_{DS(on)}$ ) and more efficient as far as the conduction losses are concerned, we prefer low voltage design. Table I gives the specifications to be used for the design of the proposed inverter system. The maximum converter input voltage 108.5 V for the selected PV module arrangement. The success of the proposed inverter system is very much related to the success in the design and the practical realization of the flyback transformers. As aforementioned, the flyback transformers have to store large amount of energy and then transfer it to the output through magnetic coupling at every switching cycle. Therefore, during the design process, the strategies that first create the most effective energy storage mechanism and second the most optimum and efficient energy transfer path must be employed. Firstly, the magnetizing inductance of the flyback transformer  $L_m$  is determined under nominal conditions [10]-[13]. Using 88 V for  $V_{PV}$ , 40 kHz for  $f_s$ , 1950 W for  $P_{PV}$ , 3 for  $n_{cell}$ , and 0.3333 for  $D_{peak}$ ,  $L_m$  is calculated as 8.27  $\mu$ H. Rounding this result to 8  $\mu$ H, the practical value of  $D_{peak}$  is calculated as 0.3278.

The control system is designed to perform two important control jobs simultaneously without using a feedback loop. While it is harvesting the maximum power available in the solar cells, it must pump that power into the utility grid with high power quality. For the first job, it should regulate a proper dc current  $I_{PV}$  and voltage  $V_{PV}$  at the PV interface for maximum energy harvesting. For the second job, it must provide control to convert the dc current, which comes from the panels and continuously regulated for the MPPT purpose, into ac current at the grid interface for power injection. In addition, this ac current should be synchronized with the grid frequency, should have low harmonic distortion, and a power factor close to unity. Because of its implementation simplicity, perturb and observe (P&O) method is selected as the MPPT algorithm. Fig. 3 shows the algorithm.

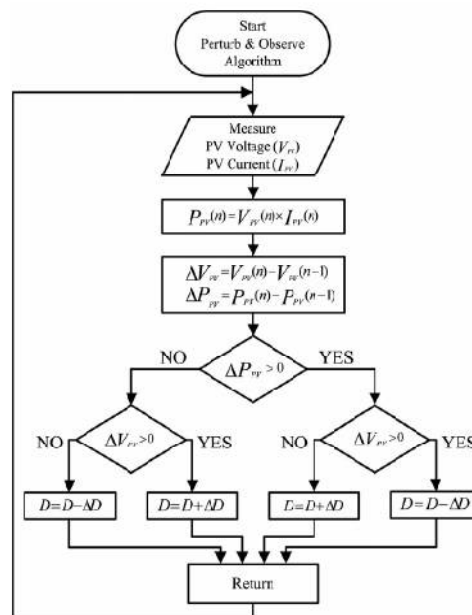


Fig. 3. Flow chart of P& O algorithm.

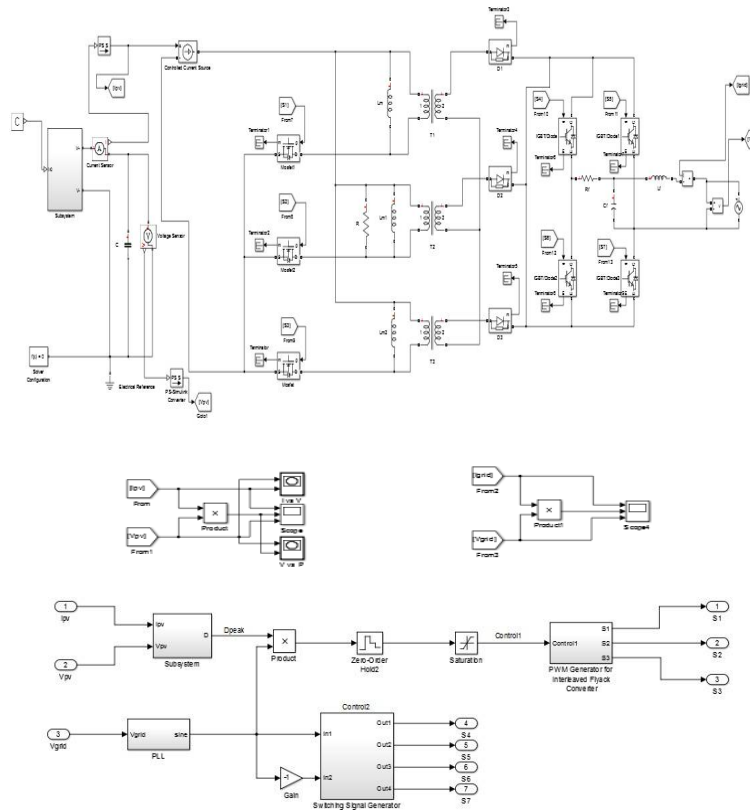
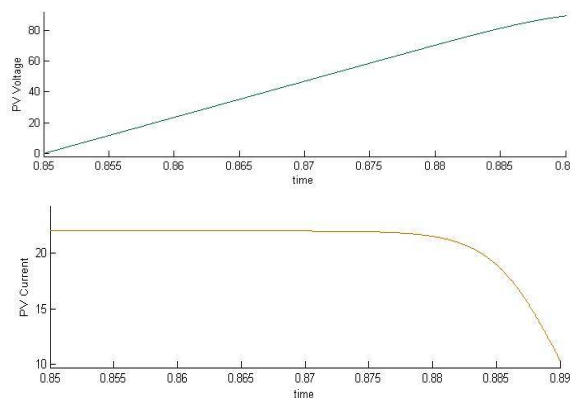


Fig. 4. . Simulation set up of proposed inverter system

#### IV. SIMULATION SET UP & DISCUSSIONS

Simulations are done to verify the design, also to determine some of the hardware requirements. For example, current ratings of the capacitors, inductors, cables, and so on can be easily determined from the simulation results. The proposed system is verified with MATLAB/SIMULINK version 2013a. Fig. 4. shows the simulation setup of proposed system. The top trace in Fig. 5 shows the Simulated Photo voltaic Power, Voltage and Current. The output PV Voltage



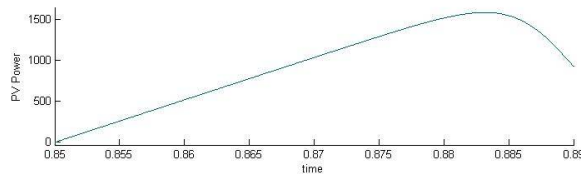


Fig. 5. Simulated Photo voltaic Power, Voltage and Current.

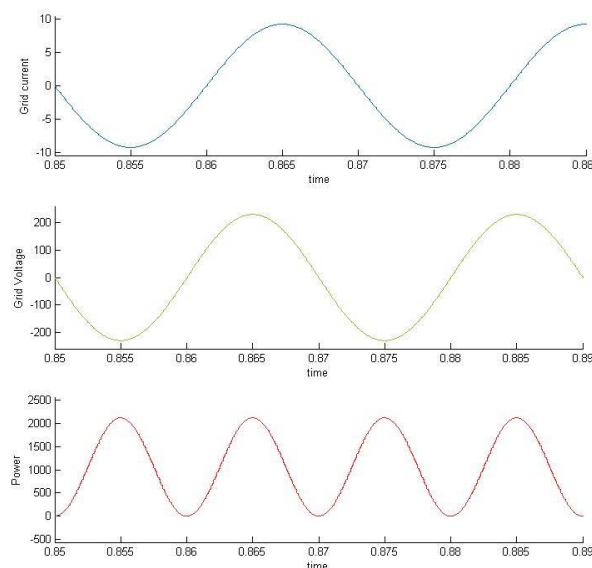


Fig. 6. Simulated waveforms of the grid Power, voltage and current.

is 88V and PV Current is around 22A. In addition, Fig. 6 shows the simulated waveforms of the grid Power, voltage and current.

## V. CONCLUSION

This paper has presented the design and simulation verification of grid-tied interleaved flyback inverter operated in DCM. The main design objective is to implement interleaved flyback inverter topology at high power. The study included analysis and simulation steps where the number of interleaved cell is determined. The three cell interleaving is optimum because it is low cost, small size and good performance. Here the perturb and observe algorithm used for MPPT. It is the optimum control method to track maximum power.

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