A Four Stage Flyback Based Micro inverter For Remote Area Residential Applications

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Abstract: PV inverter topologies are gaining popularity day by day due to the abundance of the renewable energy sources. In order to avoid the difficulties due to partial shading conditions and pollution, there are several micro inverter topologies exist. The micro inverter will convert the PV module voltage of 15-45V DC to 230V, 50Hz AC which is compatible with the grid voltage. This paper presents a four stage fly back based micro inverter for residential applications in remote areas. The inverter system rated at 2KW is developed by interleaving four flyback cells with an added benefit of reducing the passive elements. The analysis of proposed fly back inverter and the source of proposed system i.e. photo voltaic array are simulated in MATLAB 2016a software. Hill climbing algorithm is used to track the maximum power.

Keywords: Discontinuous Current Mode(DCM), Maximum Power Point Tracking(MPPT), Photo Voltaic(PV), Pulse Width Modulation(PWM).

I. INTRODUCTION

There is a growing demand for renewable energy systems based on the mounting effects of global climate change. Solar energy generation, specifically photovoltaic (PV) is an attractive option because it diversity in the energy generation and will not emit any radiations during operation. The increasing evidence and effects of climate change have created a rising demand for cleaner, greener and more renewable sources of energy generation. This demand was created in order to offset and reduce the reduction of green house gas emissions caused by traditional energy generation sources, such as fossil fuels. PV energy generation is one of the most promising emerging technologies which had seen a significant emergence worldwide over the past decade. [1]

PV systems are generally installed with grid connection. If the PV system cost decreases, and government provide beneficial energy production conditions, the payback time of the system will be decreased and the surplus will be satisfactory for the customer which leads to an increase of PV system installations all over the world and a reduction of system payback time.[2]

For an efficient PV system, one of the most important facts can be stated as the inverter apart PV panel forming an interface between the PV panel and the utility grid for an on grid systems. Among these inverters, micro-inverters are the new trend for the residential rooftop solar applications where the power capacity is relatively small such as 3-5kW or less. Furthermore, there are various topologies used in micro inverters grouped according to their DC-link configurations, isolation, number of power stages, etc.[3]

Micro inverters connected to a single PV panel are becoming the trend for the future of grid-connected PV systems due to the following reasons:

1. Improved energy harvest.
2. Improved system efficiency.
3. Lower installation costs.
4. Plug-n-play operation.
5. Enhanced flexibility and modularity.

Fly back converters are most commonly used SMPS circuit for low power applications. The overall circuit topologies of fly back converters are simpler than other SMPS circuits, and will be suitable for power control. The ability of fly back topology is that combining of energy storage inductor with the transformer. This is the main difference of fly back 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 fly back converter with good performance, which is the primary research contribution also try to conserve the cost advantage [4]-[7]. A fly back 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 fly back converter at low power as micro inverters. As a result, this topology has limited role in the PV applications. The interleaving of high-power fly back 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 hill climbing. It is the most widely used algorithm due to its simple structure and lesser required parameters.

II. PROPOSED SYSTEM CONFIGURATION AND ANALYSIS

There are two parts in PV ac module system. The first one is PV module that generates power between 1.5KW and 2KW. The second one is the power conditioner that is to convert dc power to ac power.

A. System Structure and Operation

Fig. 1 shows the circuit schematic of proposed system. It consist of a decoupling capacitor, fly back converter, H bridge inverter, low pass filter, MPPT controller A 2KW solar micro inverter is designed using an interleaved flyback based inverter. The PV modules are the energy resources available. Considering all its advantages, an interleaved flyback converter is implemented to boost the PV modules wide range voltage (18 V to 45 V) to a high-voltage dc bus, 200 V dc. A four-stage interleaved flyback converter is easy to control and the active clamp circuit can easily be used. However, using a two-stage interleaved flyback converter for a 320 W solar micro-inverter will require each stage to transfer at least 160W at maximum PV output power. The drawback of a flyback transformer rated at high power is the high peak current ripple circulating in the circuit, resulting in lower efficiency and poor reliability. The solution proposed in the paper is not applicable to this design since it does not provide the galvanic isolation. To avoid the high peak ripple current to flow through each flyback transformer, a four-stage interleaved flyback converter is proposed.[8]

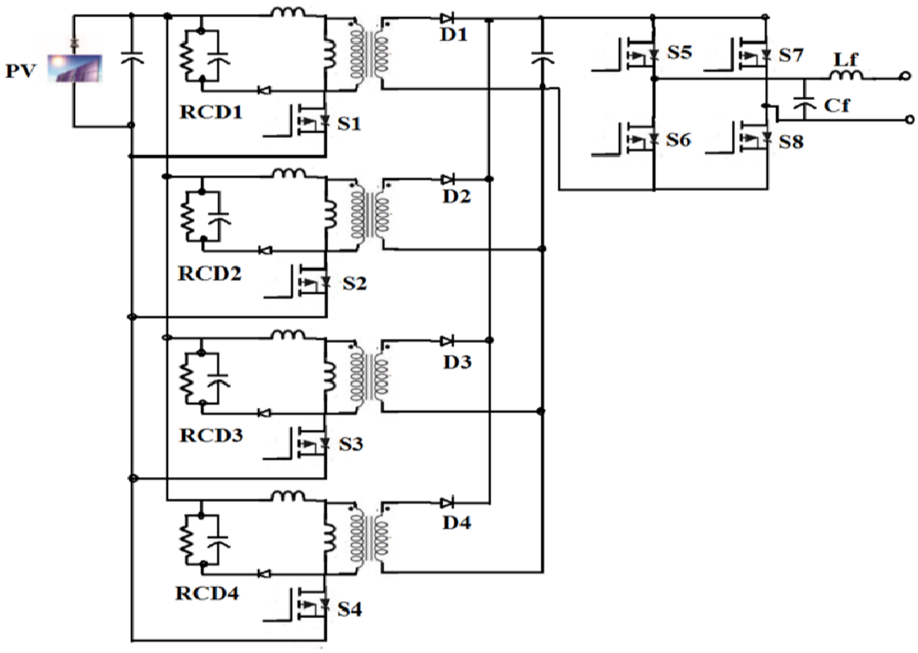

Fig. 1: Four stage interleaved flyback converter

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 fly back 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 fly back 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 fly back 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 sinusoidal 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 the proposed system, it is important to analyze the flyback converter. A particular switching period is considered for the analysis. At that time the grid voltage and duty ratios are at its maximum values. Fig. 2 shows the control signal; fly back transformer primary voltage and magnetizing current. Here the wave form represents DCM operation [5]-[7]. When fly back switch is turned ON, current I_{PV} from PV source delivered.

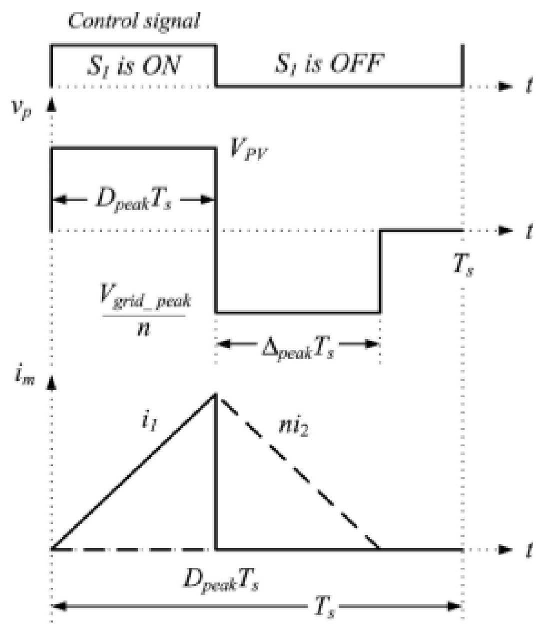

Fig. 2: Flyback switch control signal, Flyback transformer primary voltage, Magnetizing current

When switch is turned OFF, the average power drawn from PV panel equal to the active power produced at the inverter.

III. DESIGN OF THE PROPOSED SYSTEM

The major designing parts are power converter part and control part. The switching frequency for the inverter and the interleaved flyback converter are 20 kHz and 40 kHz, respectively. 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_{DDS}(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.

TABLE I
DESIGN SPECIFICATIONS

Design Parameters	**Specifications**
PV model and maximum power	BP365, 65W
Open circuit voltage and short circuit current per panel	43.2V, 10.30A
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	1950W
MPPT energy harvesting efficiency	>98%
Switching frequency of fly back converter	40KHz
Switching frequency of H bridge inverter	20KHz
Number of interleaved cells	4

The maximum converter input voltage 45 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 fly back transformers. As aforementioned, the fly back 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.

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 IPV and voltage VPV 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, hill climbing method is selected as the MPPT algorithm. Fig. 3 shows the algorithm.

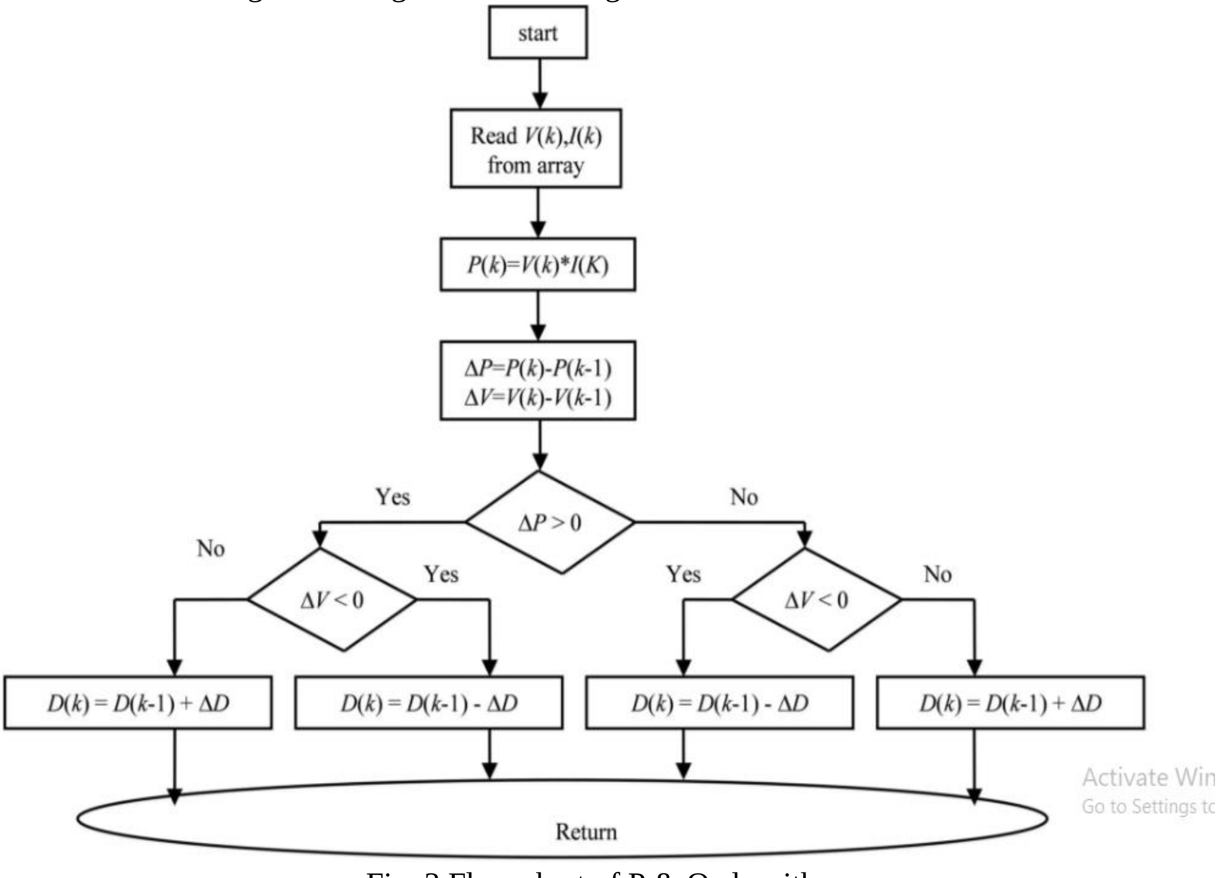

Fig. 3 Flow chart of P & O algorithm

IV. SIMULATION SETUP AND 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 2016a. Fig. 4. shows the simulation setup of proposed system. Both the performance of the interleaved flyback converter and the overall solar micro inverter are simulated. The interleaved flyback converter is implemented to boost the PV modules wide range voltage (18 V to 45 V) to a high-voltage dc bus, 200 V dc. And the unfolding bridge converts this high voltage dc to 230 V, 50 Hz alternating current. The same PWM with the same duty cycle drives each MOSFET, S1, S2, S3, S4, with a proper phase shift. The duty ratio is given as 0.8.

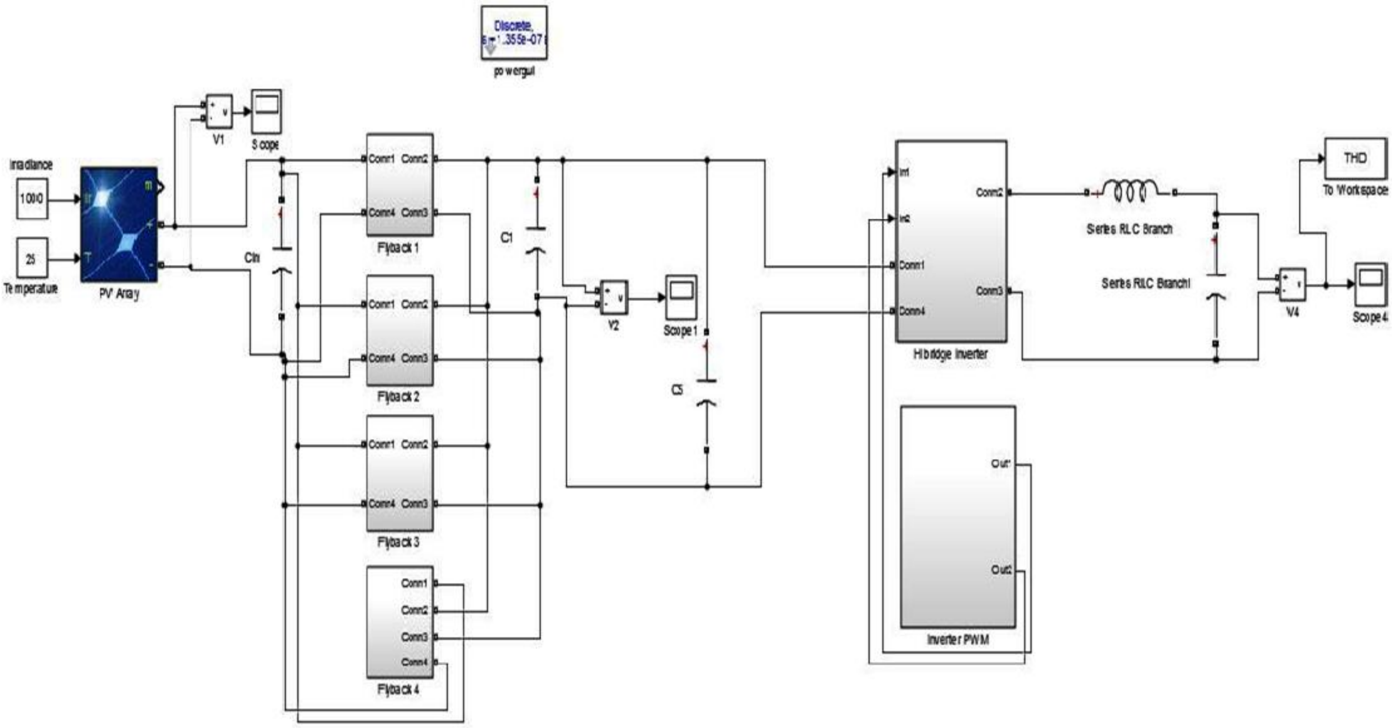

Fig. 4. Simulation diagram of flyback based micro inverter using MATLAB

The fig.5 shows the output voltage of the PV Panel. The output PV Voltage is around 45V.

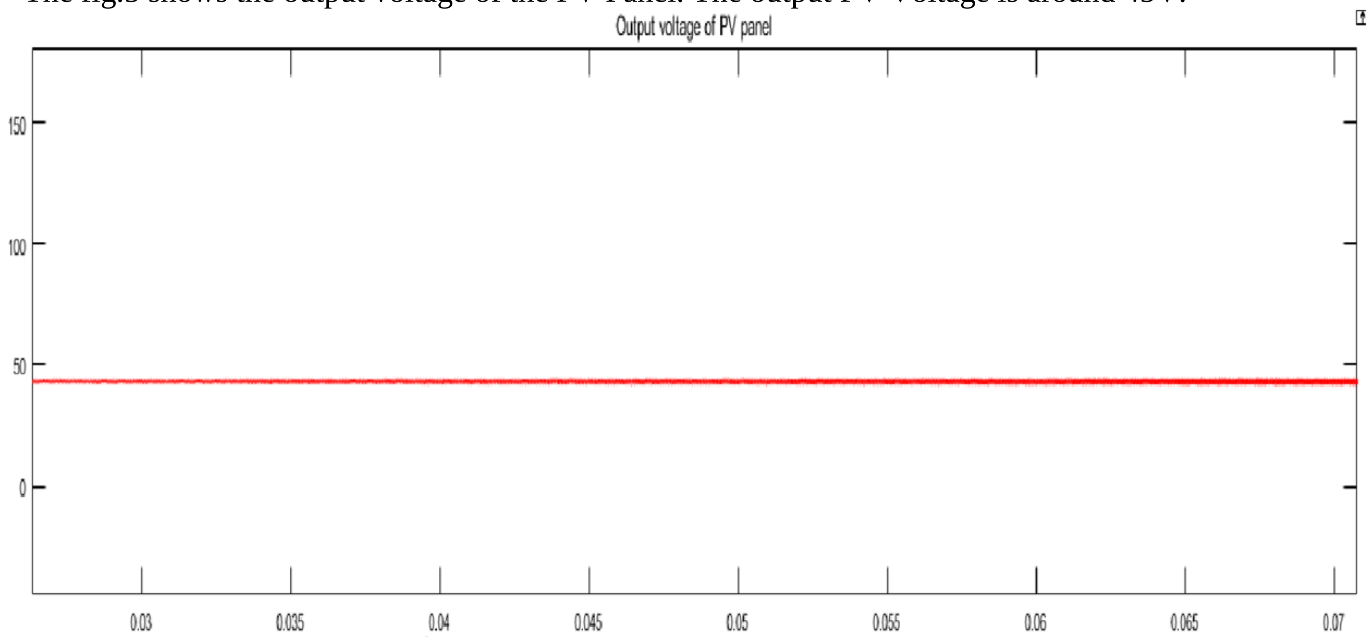

Fig. 5. Output voltage of the PV panel

Fig. 6 shows the output voltage of the fly back converter. Fig. 7 shows the output voltage of the micro inverter. The output voltage will be around 230V and of 50Hz frequency.

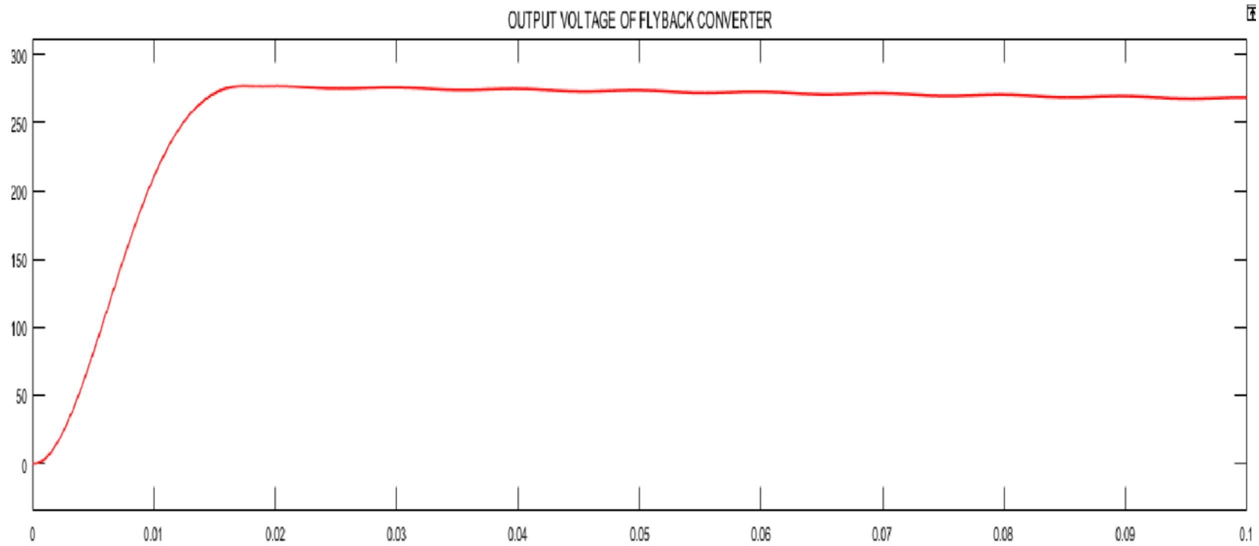

Fig. 6. Output voltage of the flyback converter

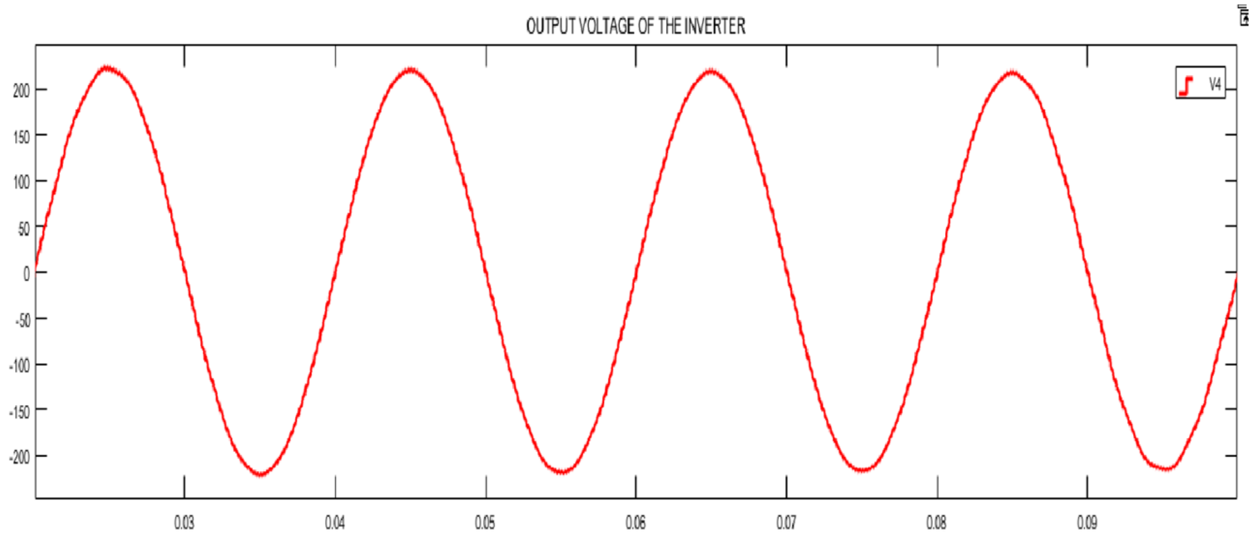

Fig. 7. Output voltage of the micro inverter

Sinusoidal pulse width modulation is used for controlling the inverter switches. The THD analysis of the inverter output is 1.19% and easily meets the IEEE 1547 requirement of less than 2.5%.

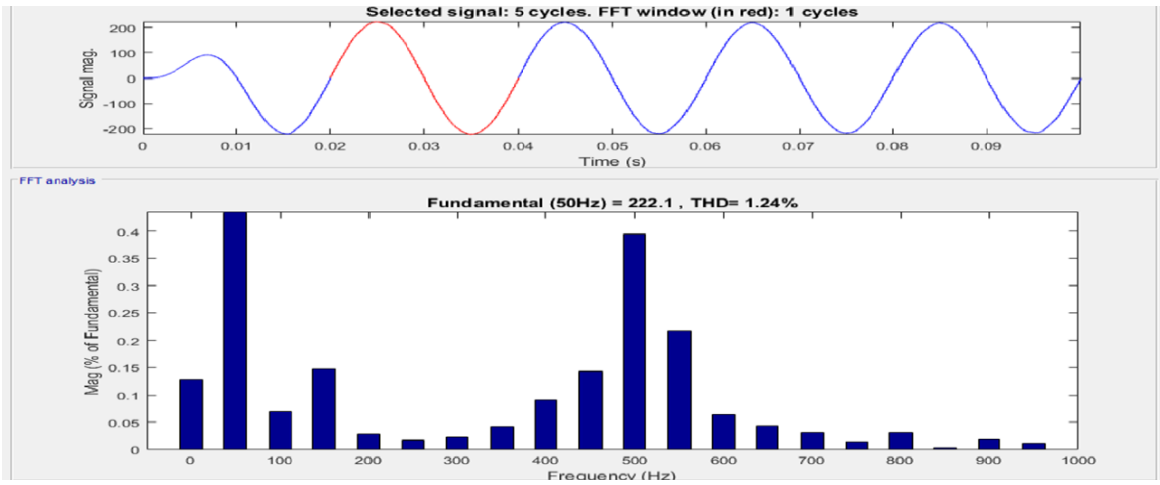

Fig. 8. THD waveform

V. CONCLUSION

This paper has presented the design and simulation verification of interleaved fly back inverter operated in DCM. The main design objective is to implement interleaved fly back 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. A central – type PV inverter for small electric power system applications rated at 2kW is implemented based on the interleaved flyback converter topology. The 2 kW power level is achieved by interleaving of three flyback cells each rated at 700 W. The flyback topology is selected because of its simple structure and easy power flow control with high power quality outputs at the grid interface. The THD of the output current is measured as 1.24%.

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