MICROINVERTER WITH HIGH EFFICIENCY SNUBBER CIRCUIT FOR A GRID INTERACTIVE PV PANEL

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Abstract: An isolated grid-connected micro-inverter for photovoltaic (PV) applications based on interleaved flyback converter . The converter operating in discontinuous current mode with high efficiency adaptive snubber circuit. The inverter topology for PV micro-inverter application performs the maximum power point tracking (MPPT) of PV module. During the turn –off time the snubber circuit limits the drain-to-source voltage overshoot of the flyback's switch. This enables the use of lower voltage MOSFET. It also recovers the stored energy in the leakage inductance of the flyback transformer and provides soft switching for the main flyback switch. The soft switching is done by limiting the rising time of the voltage across the MOSFET during the turn off process. So that it results higher efficiency. Thus the operation of the flyback micro-inverters is studied analytically and the performance is measured by hardware setup.

***IndexTerms* - Snubber, Micro inverter topology, PV panel.**

I. INTRODUCTION

Renewable energy is the energy that is collected from resources which are naturally occurs, such as sunlight, wind, rain, tidal and heat from geothermal. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off grid) energy services. Recently, the Photovoltaic (PV) power generation structure plays a vital role in distributed electric power systems and Micro grids (MGs) [1] – [4]. Using an Inverter, the DC power from the PV array can be conveniently converted to AC similar to connection with normal power grid. There are only two primary disadvantages to using solar power: amount of sunlight and cost of equipment. The best way of lowering the cost of solar energy is to improve the cell's efficiency. In this paper a new high efficiency interleaved flyback inverter which operates in Discontinuous conduction mode (DCM) mode is presented. The power delivered by a PV system of one or more photovoltaic cells is dependent on the irradiance, temperature, and the current drawn from the cells. The power generated from solar panel is capable of supplying the local load as well as the grid at synchronous conditions. The PV systems supply solar electricity through an inverter directly to the load and to the electricity grid. This paper consists of six sections including introduction. Section II discussed existing system, Section III discussed proposed system, Section IV discussed parameter design, Section V discussed results and discussion and Section VI discussed hardware results.

II. EXISTING SYSTEM

In the Existing system the energy storage inductor and the transformer are separate elements. While the inductor is responsible for energy storage, the transformer is responsible for energy transfer over a galvanic isolation. The combination of these two components in a fly back topology eliminates the bulky and costly energy storage inductor and therefore leads to a reduction in cost and size of the converter. Practical implementation of a transformer with relatively large energy storage capability is always a challenge. A fly back converter built with a transformer that has large leakage flux and poor coupling will have poor energy transfer efficiency. Mainly for this reason, the fly back converters are generally not designed for high power. As a result, the fly back topology finds a limited role in PV applications only at very low power as micro inverter.

III. PROPOSED SYSTEM

In this paper, an interleaved high-power fly back inverter for photovoltaic applications is proposed. The simple structure of the fly back topology and easy power flow control with high power quality at the grid interface are the key motivations for this work. The fly back converter is recognized as the lowest cost converter among the isolated topologies since it uses the least number of components. This advantage comes from the ability of the fly back topology combining the energy storage inductor with the transformer. The converter is operated in DCM for easy and stable generation of ac currents at the grid interface. Maximum power point is a unique operating point supplying maximum power to the load which is present in a PV array. Tracking the maximum power point of the PV array is done to improve the efficiency of the photovoltaic energy system. MPPT is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power capable of PV module. The operations are implemented in Matlab software.

3.1 BLOCK DIAGRAM

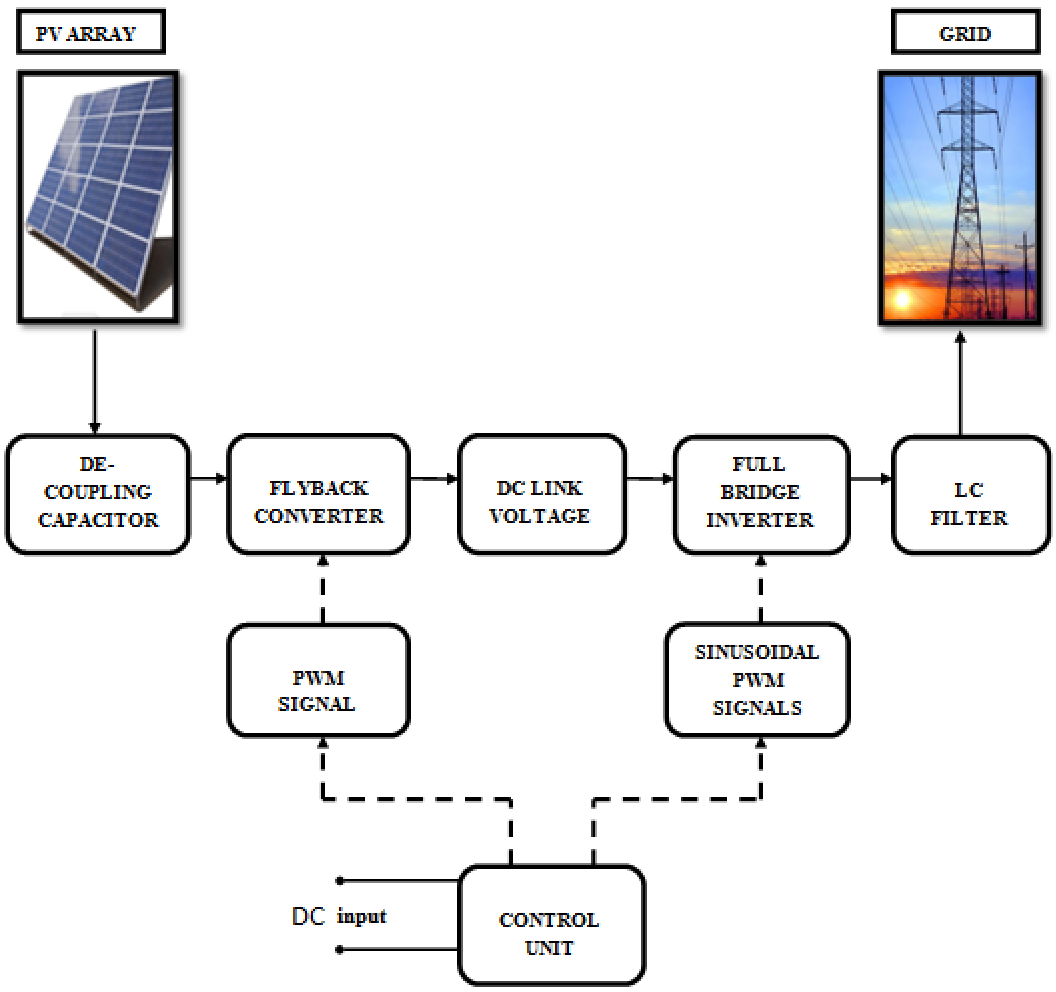

Fig 3.1 General block diagram

The description of the above Block diagram in Fig 3.1 is given below,

- **Input supply:** Solar Energy.
- **Filter:** It is used to remove unwanted or undesired frequencies from a signal.

- **Grid:** An electric grid is a network of synchronized power providers and consumers that are connected by transmission and distribution lines and operated by one or more control centers. When most people talk about the power "*grid*," they're referring to the transmission system for electricity.
- **Inverter:** It operates from a dc voltage source or a dc current source and converts it into ac voltage or current.
- **PWM generator:** It is used to generate PWM pulses to make a switching signal.
- **Converter:** It converts the voltage of an electric device, usually alternating current (AC) to direct current (DC).
- **Fly-back converter:** This is similar to buck-boost converter which is with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation.
- **Interleaved converter:** High-current systems often use multiphase converters called interleaved converters. Multiphase regulators can have better ripple and better response times than single-phase regulators.
- **De-coupling Capacitor:** A decoupling capacitor acts as a local electrical energy reservoir. Capacitors, like batteries, need time to charge and discharge. When used as decoupling capacitors, they oppose quick changes of voltage. If the input voltage suddenly drops, the capacitor provides the energy to keep the voltage stable. Similarly, if there is a voltage spike, the capacitor absorbs the excess energy.
- **Coupling capacitors:** It is used to pass AC signals in an electronic circuit while blocking DC. They are placed between the two parts of the circuit.
- **MPPT Control:** It is an electronic DC to DC converter that optimizes the match between the solar array, and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels down to the lower voltage needed to charge batteries.

3.2 SOLAR PHOTOVOLTAIC SYSTEMS

The term solar panel is best applied to a flat solar thermal collector, such as a solar hot water or air panel used to heat water, air, or otherwise collect solar thermal energy. But 'solar panel' may also refer to a photovoltaic module which is an assembly of solar cells used to generate electricity. In all cases, the panels are typically flat, and are available in various heights and widths. An array is an assembly of solar-thermal panels or photovoltaic (PV) modules shown in fig 3.2 the panels can be connected either in parallel or series depending upon the design objective. Solar panels typically find use in residential, commercial, institutional, and light industrial applications [5] - [6].

Fig 3.2 Solar panel arrangement

3.3 MAXIMUM POWER POINT TRACKING

Maximum power point tracking (MPPT) is a technique used with wind turbines and photovoltaic (PV) solar systems to maximize power output. A MPPT algorithm are necessary in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is required in order to obtain the maximum power from a solar array. These techniques differ in many aspects such as required sensors, complexity, cost, range of effectiveness, convergence speed, correct tracking when irradiation and/or temperature change, hardware needed for the implementation or popularity, among others. Most of these methods yield a local maximum and some, like the fractional open circuit voltage or short circuit current, give an approximated MPP, not the exact one. In normal conditions the V-P curve has only one maximum, so it is not a problem. However, if the PV array is partially shaded, there are multiple maxima in these curves. In order to relieve this problem, some algorithms have been implemented [7]. Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce and it is shown in Fig 3.3. The fill factor, abbreviated *FF*, is a parameter which characterizes the non-linear electrical behavior of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar cell to the product of Open Circuit Voltage V_{oc} and Short-Circuit Current I_{sc}. In tabulated data it is often used to estimate the maximum power that a cell can provide with an optimal load under given conditions,

$$P=FF*V_{oc}*I_{sc}$$

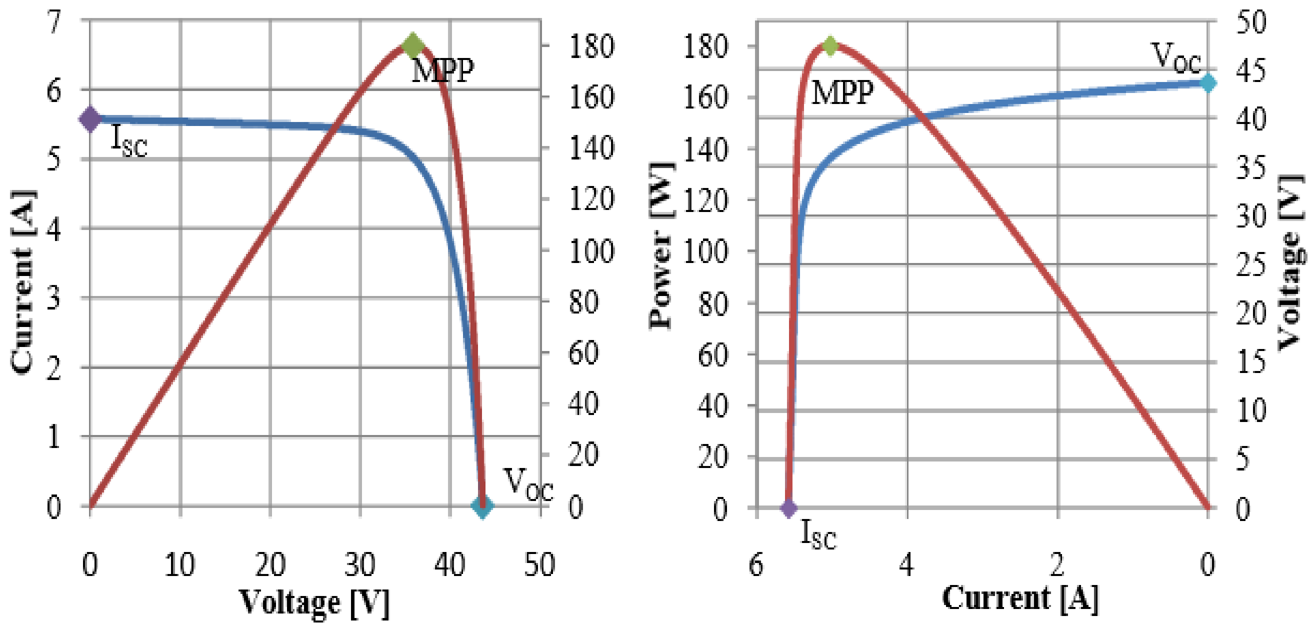

Fig 3.3 ***I-V and P-I characteristics***

3.4 CIRCUIT FOR PROPOSED SYSTEM

Photovoltaic (PV) micro-inverters have gained a significant attention for grid-connected PV system applications during the past few years because of improved energy harvest. Various inverter topologies for PV micro-inverters applications have been introduced that perform the maximum power point tracking (MPPT) of PV module, high step-up voltage amplification. Among them, the fly back based micro inverter is one of the most attractive solutions due to its simple structure and control.

3.4.1 Flyback Microinverter With A Snubber Circuit

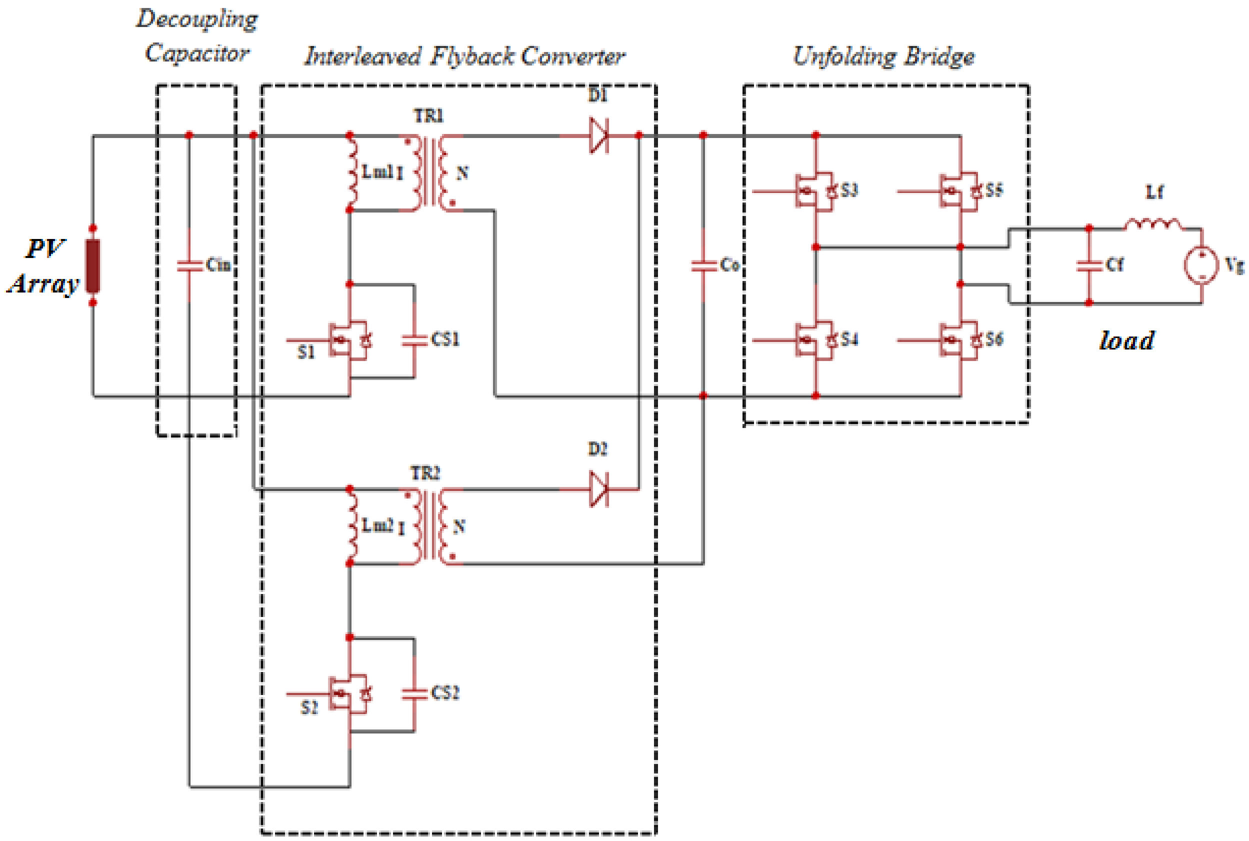

Fig. 3.4 Proposed Fly back micro inverter with Adaptive Snubber

Fig. 3.4 illustrates the conventional fly back micro-inverter, which consists of decoupling capacitors, interleaved fly back converter, unfolding bridge, and CL filter. The unfolding bridge is switched at line frequency by a simple Square-wave control, generating a rectified sinusoidal waveform at the dc-link between the interleaved fly back converter and unfolding bridge. The PV source is applied to a two cell interleaved fly back converter through a decoupling capacitor. Each fly back converter uses a metal–oxide–semiconductor field-effect transistor (MOSFET) for switching at the primary side, a fly back transformer, and a diode at the secondary side. The topology also has to employ a full-bridge inverter and a low-pass filter for proper interface to the grid.

When the fly back switches (*S*1, S2) are turned ON, a current flows from the common point (the PV source) into the magnetizing inductance of the fly back transformers, and energy is stored in the form of magnetic field. During the on time of the switches, no current flows to the output due to the position of the secondary side diodes; therefore, energy to the grid is supplied by the capacitor C_f and the inductor L_f. When the fly back switches are turned OFF, the energy stored in the magnetizing inductances is transferred into the grid in the form of current. So, the fly back inverter acts like a voltage-controlled current source. The converter is operated in DCM for easy and stable generation of ac currents at the grid interface. The DCM operation of converter under open-loop control produces triangular current pulses at every switching period. If sinusoidal pulse width modulation (PWM) method is used for control, the inverter will regulate these current pulses into a sinusoidal current in phase with the grid voltage. The full-bridge inverter is only responsible for unfolding the sinusoidally modulated dc current packs into ac at the right moment of the grid voltage. Since the switches of the inverter are operated at the grid frequency, the switching losses are insignificant [8] – [12]. Only conduction losses are concerned. For this reason, the bridge can use thyristor or even transistor switches for lower cost. However, for easy control also the availability in the laboratory for fast prototyping, we prefer using insulated-gate bipolar transistor (IGBT) switches for this design. But, the final prototype will not use IGBTs. The low-pass filter after the IGBT inverter is responsible for supplying a current to the grid with low THD by removing the high frequency harmonics of the pulsed current waveforms. The first flyback cell is done over one particular switching period when both the grid voltage and the duty ratio are at their peak values [13] –[16].

IV. DESIGN PARAMETERS

Power=10W

V_{mp}=17V

I_{mp}=0.56A

V_{oc}=21.916V

I_{sc}=0.769A

Input parameters

V_{min}=14.2V

V_{max}=17.2V

I_{in}=2.91A

Output parameter

V_{out}=48V

I_{out}=0.19833A

F_s=50*khz*

η = 95%

Duty ratio=0.4

T_{on}=0.000004s

Average Input current = Input power/ V_{min}

= 10/14.2

= 0.7042A

Peak current is given by the relation :

Average current = (Peak current*Duty cycle)/2

Therefore,

Peak current = (Average input current*2)/Duty cycle

= (0.7042*2)/0.4

= 3.521A

Turns ratio =V_{out}/V_{min} = 48/14.2= 3.3802

Secondary peak current = (2*Load current)/T_{on}

= (2*0.198)/0.4

= 0.9916A

L(primary) :

Vin = (L(primary) * I_{peak} /T_{on})

Therefore, L(primary) = ((T_{on}*V_{in})/I_{peak})

= (8*10^-6*14.2)/3.521)

= 0.0000322

L(secondary):

= L(primary) * (Turns ratio)^2

= 0.0000322*(3.38)^2

= 0.00036 H

N(primary) = ((L(primary) * Primary peak current)/(B*sat**area))

Where, B*sat* = 0.0032T, A*e* = 0.00535sq.cm

N*p* =((3.22*10^-6*3.521)/(0.0032*0.00535))

N*p*= 6.6224turns

Secondary turns = No.of primary turns * turns ratio

= 6.622*3.802

= 22.4299

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V. RESULTS AND DISCUSSION

The PV panel is given the values of temperature, Rs, Rn and n and the output voltage and current is given to the fly back converter. The switch provided to operate the converter is provided with a gate signal which is calculated using MPPT (P&O) algorithm. The AC output of the converter is converted into variable DC by using diode rectifier. Then the variable DC is converted into pure DC by passing through the single phase full bridge rectifier. The gate pulse to the rectifier is given by comparing the output voltage of the system and the carrier signal at a given time period. The variable AC output with ripples from the inverter is filtered by use of LC filter. The output voltage obtained is synchronized with the grid. Fig 5.1 shows the Matlab simulation of the proposed system.

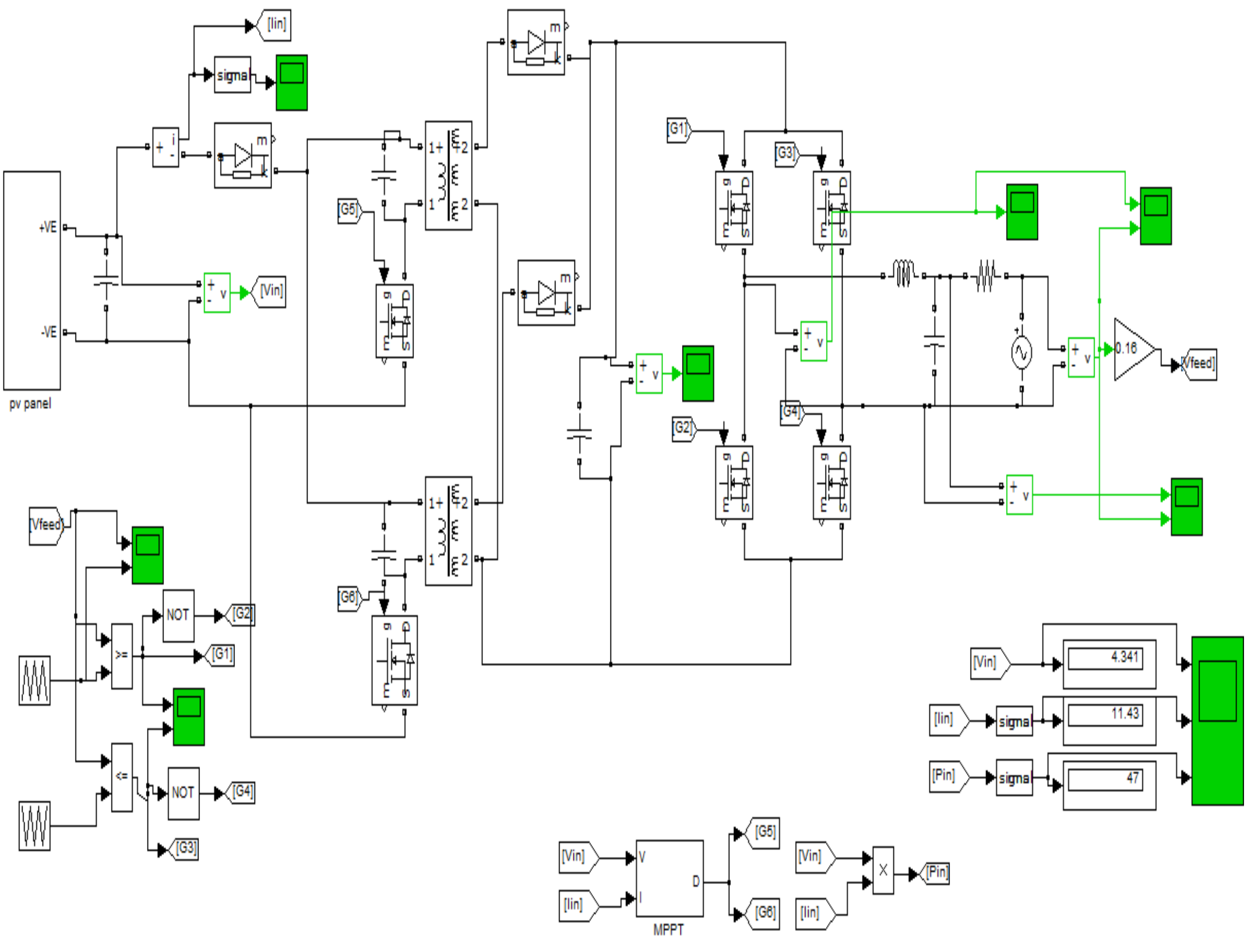

Fig.5.1 Simulation for the proposed system

5.1 SIMULATION OUTPUTS

5.1.1 FLYBACK MICROINVERTER WITH ADAPTIVE SNUBBER CIRCUIT - WITHOUT FILTER

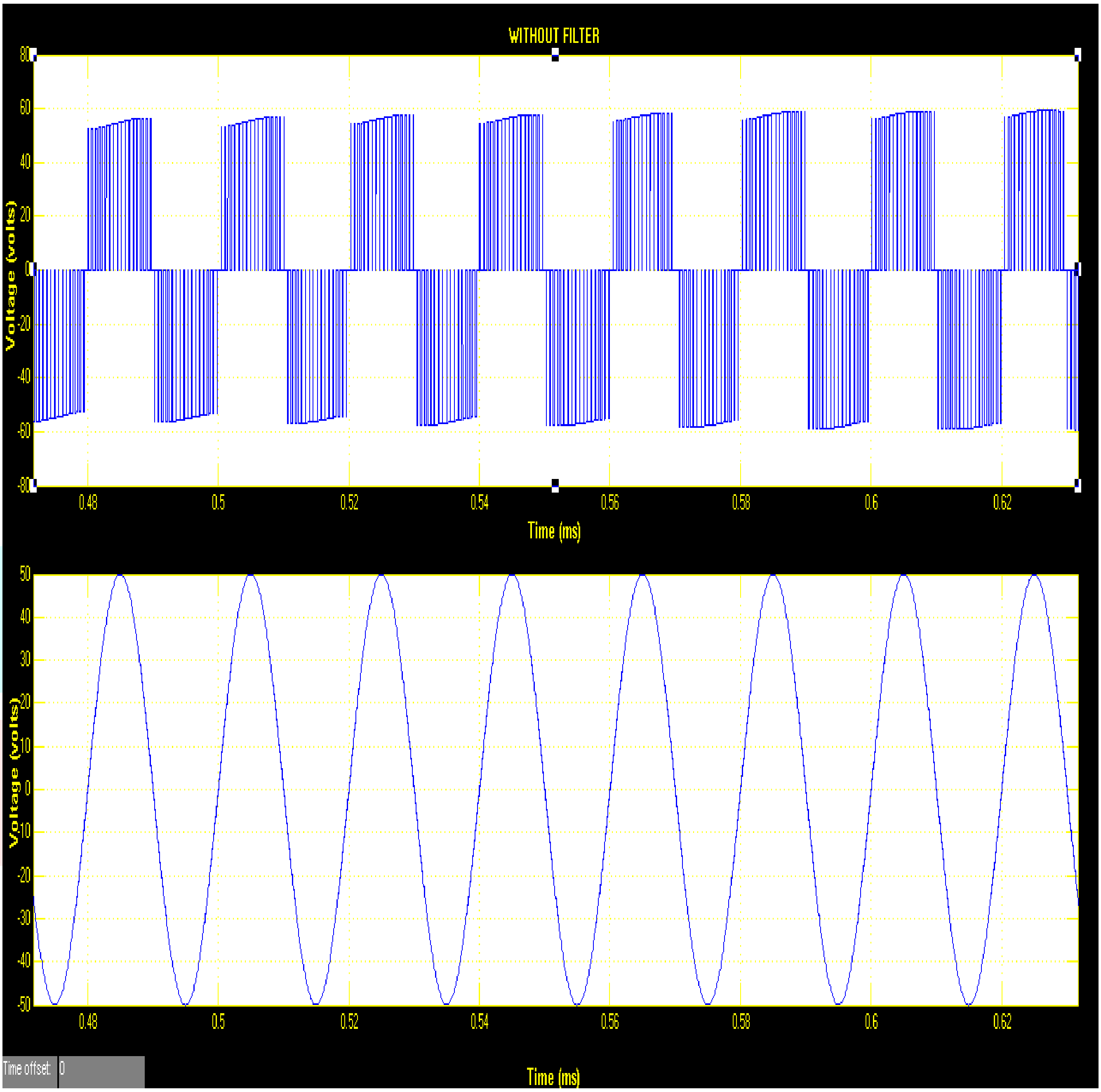

Fig. 5.2 Fly back micro inverter without filter

5.1.2 FLYBACK MICROINVERTER SYNCHRONIZED WITH GRID WITH FILTER

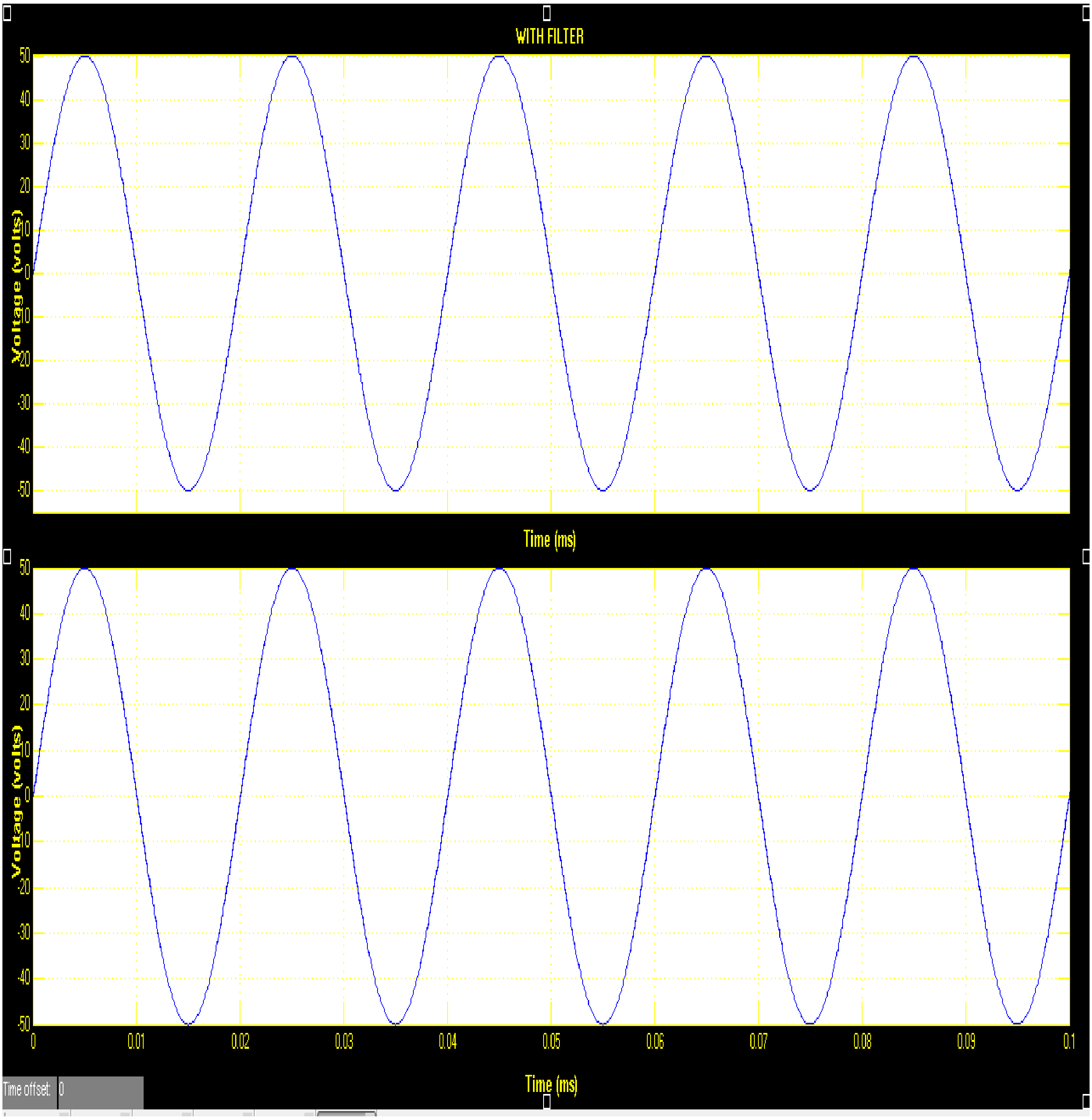

Fig. 5.3 Fly back micro inverter with filter

VI. HARDWARE RESULTS

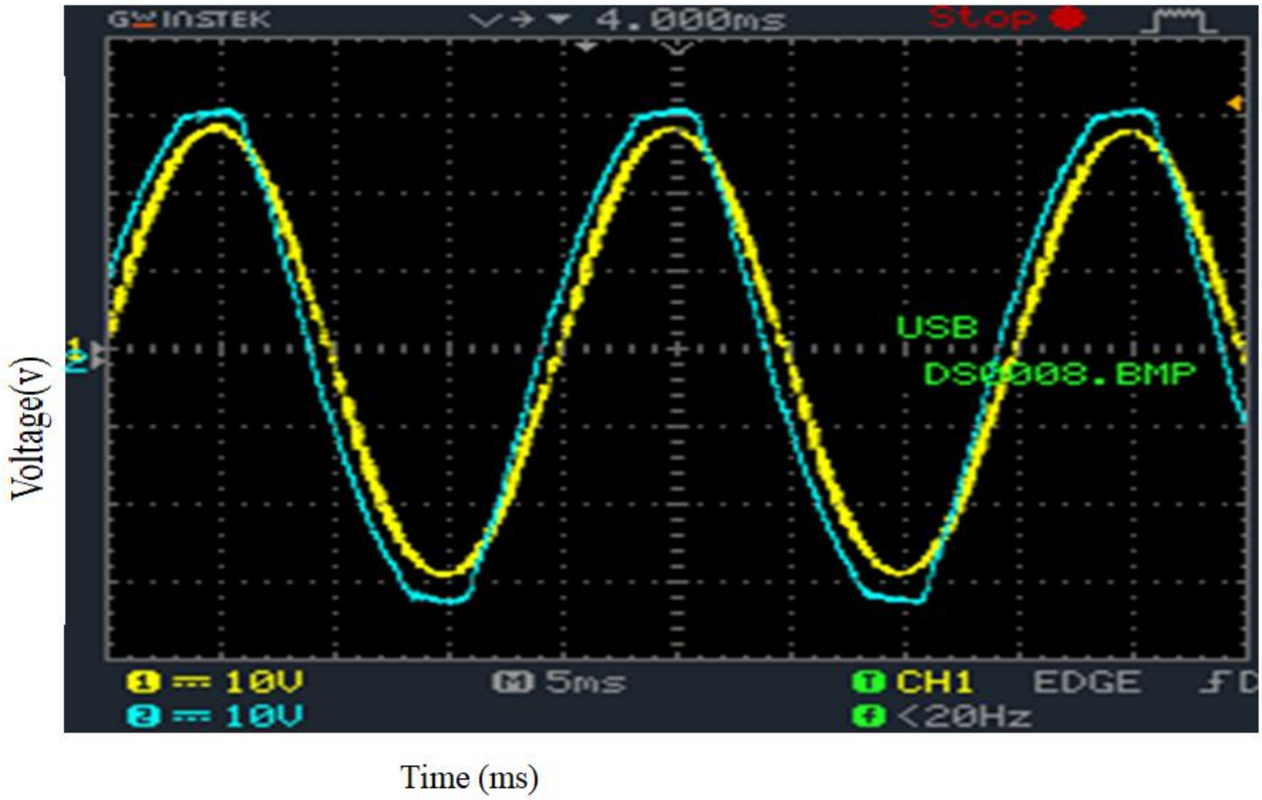

Fig. 6.1 Unsynchronised Output

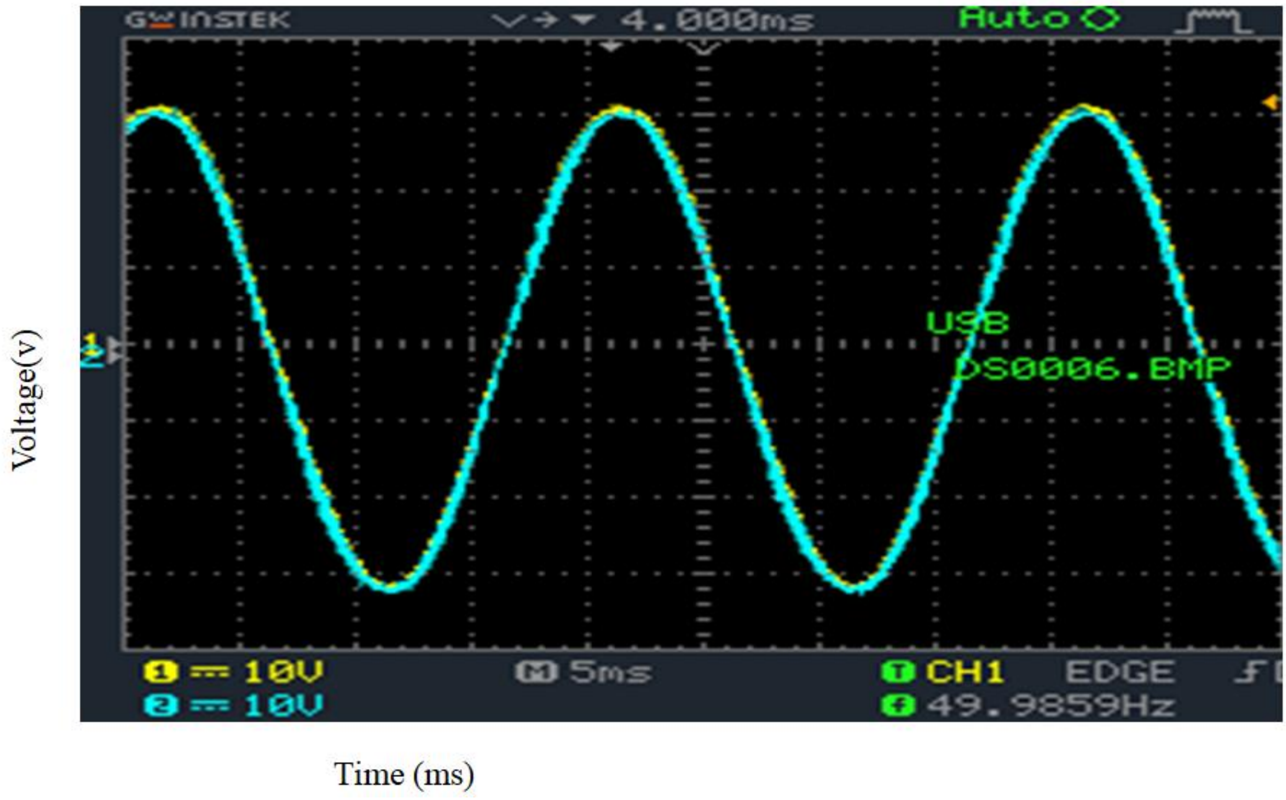

Fig. 6.2 Synchronised Output

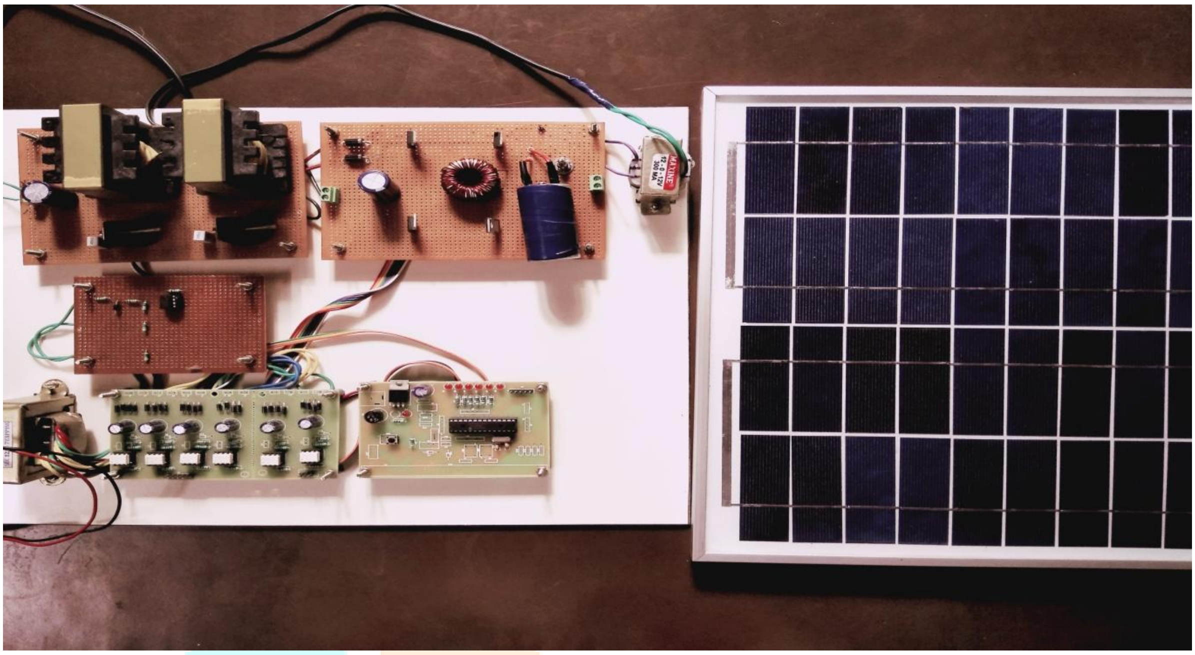

Fig. 6.3 Flyback Micro Inverter With Snubber Circuit For A Grid Interactive Pv Panel

VII. CONCLUSION

In this paper, a new interleaved flyback converter based single phase full bridge inverter is designed and simulation results are verified. The flyback topology is selected because of its simple structure and easy power flow control with high power quality outputs at the grid interface. This will increase the system efficiency and also provide the better power factor correction.

VIII. REFERENCES

[1] Panagiotis Mantzanas, Markus Barwig and Thomas Duerbaum, "Analytical Calculation of the Fly back Converter Utilizing a Transformer with Saturable Magnetizing Inductance,"*IEEE Transactions on Power Electronics* 2016.

[2] Henglin Chen and Ji Xiao, "Determination of Transformer Shielding Foil Structure for Suppressing Common-Mode Noise in Fly back Converter", IEEE *Transactions on Magnetics* 2016.

[3] Mohammad Ali Rezaei, Kui-Jun Lee, Alex Huang, "A High Efficiency Fly back Micro-inverter for Photovoltaic Applications,"*IEEE Transactions on Power Electronics* 2015.

[4] F. Fongang Edwin, W. Xiao, and V. Khadkikar, "Dynamic modeling and control of interleaved fly back module-integrated converter for PV power applications," *IEEE Trans. Ind. Electron.*, vol. 61, no. 3, pp.1377–1388, Mar 2014.

[5] T. V. Thang, N. M. Thao, J.-H Jang, and J.-H Park, "Analysis and design of grid-connected photovoltaic systems with multiple-integrated converters and a pseudo-DC-link inverter," *IEEE Trans. Ind. Electron.*,vol.61, no.7, pp. 3377-3386, July 2014.

[6] Y.-H. Kim, J.-W Jang, S.-C Shin, and C.-Y Won, "Weighted-efficiency enhancement control for a photovoltaic AC module interleaved flyback inverter using a synchronous rectifier," *IEEE Trans. PowerElectron.*, vol.29, no.12, pp. 6481-6493, Dec2014.

[7] C. Olalla, D. Clement, M. Rodriguez, and D. Maksimovic, "Architectures and control of sub module integrated DC–DC converters for photovoltaic applications," *IEEE Trans. Ind. Appl.*, vol. 28, no. 6, pp. 2980–2997, Jun 2013.

[8] Z. Zhang, X.-F.He and Y.-F. Liu, "An optimal control method for photovoltaic grid-tied-interleaved fly back micro inverters

to achieve high efficiency in wide load range," *IEEE Trans. Ind. Appl.*, vol. 28, no. 11, pp. 5074–5087, Nov 2013.

[9] S. Zengin, F. Deveci, and M. Boztepe, "Decoupling capacitor selection in DCM fly back PV micro inverters considering harmonic distortion," *IEEE Trans. Power Electron.*, vol. 28, no. 2, pp. 816–825, Feb 2013.

[10] H. Hu, S. Harb, X. Fang, D. Zhang, Q. Zhang, Z. J. Shen, and I. Batarseh, "A three-port fly back for PV micro-inverter applications with power pulsation decoupling capability," *IEEE Trans. Power Electron.*,Vol. 27, no. 9, pp. 3953–3964, Sep 2012.

[11] Y. Li and R. Oruganti, "A low cost flyback CCM inverter for AC module application," *IEEE Trans. Power Electron.*, vol. 27, no. 3, pp. 1295–1303, Mar 2012.

[12] A. C. Kyritsis, E. C. Tatakis, and N. P. Papanikolaou, "Optimum design of the current-source flyback inverter for decentralized grid-connected photovoltaic systems," *IEEE Trans. Energy Convers.*, vol. 23, no.1, pp. 281–293, Mar 2008.

[13] G. H. Tan, J. Z. Wang, and Y. C. Ji, "Soft-switching flyback inverter with enhanced power decoupling for photovoltaic applications," *Electr. Power Appl.*, vol. 1, no. 2, pp. 264–274, Mar 2007.

[14] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single phase grid-connected inverters for photovoltaic modules," *IEEE Trans. Ind. Appl.*, vol. 41, no. 5, pp. 1292–1306, Sep. 2005.

[15] N. Kasa, T. Iida, and L. Chen, "Flyback inverter controlled by sensorless current MPPT for photovoltaic power system," *IEEE Trans. Ind. Electron.*, vol. 52, no. 4, pp. 1145–1152, Aug 2005.

[16] Y. Xue, L. Chang, S. B. Kjaer, J. Bordonau, and T. Shimizu, "Topologies of single-phase inverters for small distributed power generators: An overview," *IEEE Trans. Power Electron.*, vol. 19, no. 5, pp. 1305–1314, Sep 2004.