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A High Efficiency Flyback Micro-Inverter for AC-PV Module

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Abstract: The current source flyback micro inverter plays a vital role in PV applications. Presently central inverter system is replaced by micro inverter. Micro inverters are small inverters rated to handle the output of a single panel. Many converter topologies have been proposed for the AC-PV modules. Among those, the fly back inverter has been the center of attention because it satisfies the application requirements such as high voltage step-up ratio, galvanic isolation, low volume, high reliability, and provides high efficiency and relatively simple control. This paper proposes an efficient fly back inverter with mppt control. The center tapped transformer is replaced by a two winding transformer to decrease the current losses. Fly back inverter has three modes of operation. They are DCM (Discontinuous conduction mode), BCM(Boundary conduction mode) and CCM (Continuous conduction mode).By using mppt control we can avoid the problems of individual conduction modes. The performance of the proposed model is simulated in MATLAB/ Simulink environment.

Keywords: total harmonic distortion (THD), Transparent Conductive Oxides(TCO),Maximum power point tracking (MPPT),

I. INTRODUCTION

Renewable energy sources are becoming more popular due to environmental concerns and the need for more energy. Solar energy systems based on photovoltaic (PV) cells have attracted considerable interest in last few years due to free of operating cost, pollution free and inexhaustible. Solar energy systems based on micro-inverter architectures are gaining in popularity as they are less prone to shading and PV cell malfunction since each solar panel in a system has its own low power inverter. Even though the energy generation from solar panel is possible only for about 6 hours during day time it has higher power density compared to other renewable energy resources which makes it more popular. The hybrid modes of operation (DCM and BCM) of flyback inverter varies during a utility half cycle and the utilisation ratio of each module varies. At low irradiance levels if the system enters into DCM the switching frequency remains constant but the transformer is completely demagnetised before the net switching cycle. At high irradiance levels the system may enters into BCM and the switching frequency may varies and switching losses will be high. In two winding transformer configuration with mppt control avoids the problems of individual DCM and BCM. Also in BCM the variable switching frequency is very difficult for practical implementation.In early days we are using transformer less inverter to reduce size and cost. In this paper a fly back inverter with mppt control is proposed which will increases the power quality injected into the grid by reducing the THD. If we are using an inverter with center tapped configuration and operating in different modes at variance irradiance levels the appropriate control strategy is required for finding smooth transition points between different modes.

II. PROPOSED CIRCUIT CONFIGURATION

The fly back inverter with two winding transformer is shown in Fig.1.M1 is the main semiconductor switch and operates in high frequency. The high-frequency transformer transfers the energy from the PV panel to the ac utility grid. The input voltage fluctuation due to high frequency operation can be eliminated by the use of a capacitor c_{pv} at the input side. Also the mismatch between PV power output and the pulsating input power of the fly back inverter is handled by this capacitor. The sinusoidal pulse width modulation is employed for the main switch M1 to achieve a sinusoidal output current waveform. The presence of Fly back transformer provides the problems of TCO corrosion and leakage current is avoided by double grounding. The operation of fly back inverter is ensured by the secondary winding diodes. A low pass filter is used for filtering purpose at the output side.

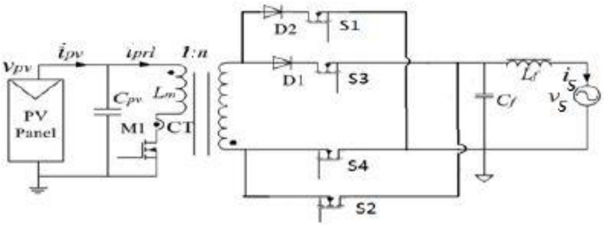

Fig 1. Proposed Flyback inverter

A. Operating Principle of flyback inverter

The flyback inverter has three modes of operation .During positive half cycle of output voltage main switch M1 is kept on and current is flowing through the primary winding of transformer. The energy induced in secondary winding transformer reverse biases the diode M1.The output is supplied by the capacitor. When switch M1 is off the diode D2 is forward biased and the current is flowing through D2-S1-Lf-S2 during negative half cycle of output voltage M1 is turned on and input is directly connected to the supply. The induced current in secondary winding reverse biases the diode D1 and output is supplied by the capacitor. When switch M1 is turned off D1 is forward biased and energy stored in the secondary supplies the load through S3 and S4.These two modes repeat many times for next half cycle of the line period and an ac waveform is obtained.

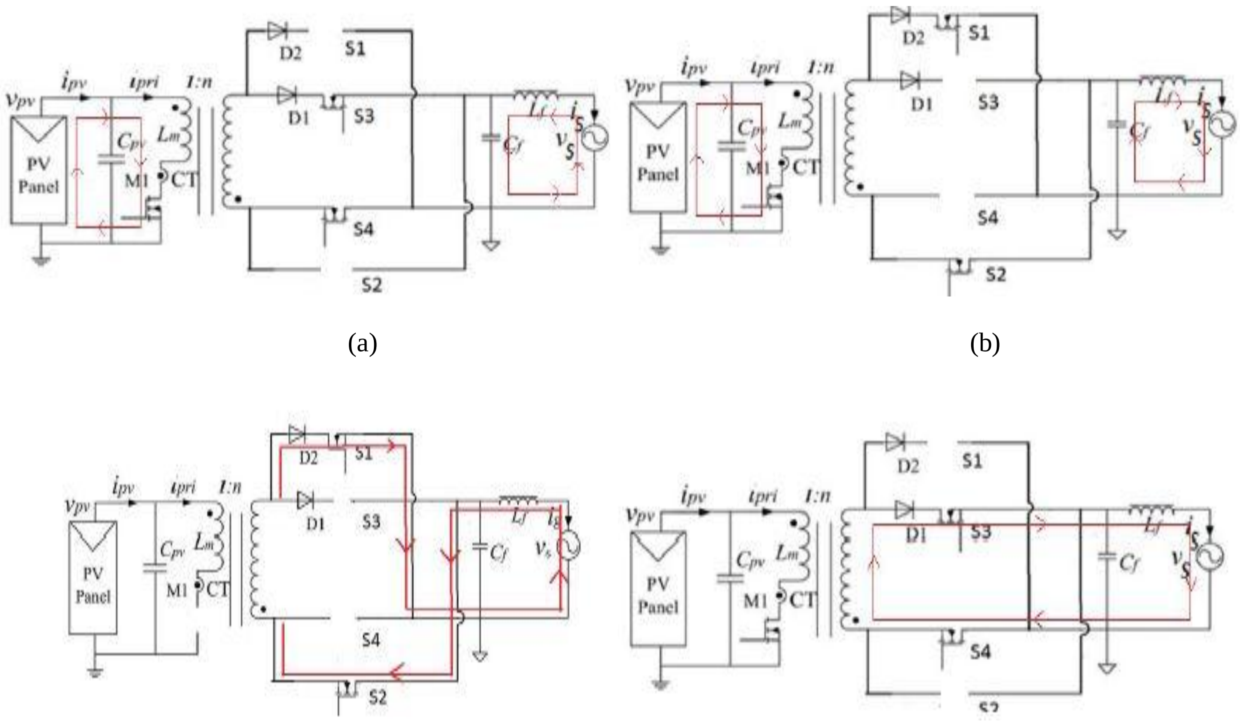

Fig. 2. Current direction during positive and negative half cycle, as shown in Fig. 2(a)–(d). (a) positive half cycle and M1 is on. (b) Negative half cycle and M1 is on. (c) positive half cycle and M1 is off. (d) Negative half cycle and M1 is off

B. Design procedure

The magnetising inductance Lm of transformer is properly designed to obtain the output waveform. The value of magnetising inductance is neither too low nor too high. If its value is too low then the switching losses on main switch will be high. Because the peak value of primary current may attain high value and current stress will be increasing. If the value of magnetising inductance is too high then the system enters into continuous conduction mode and is difficult to obtain correct output waveform. For PV panel modelling first identified the voltage and current specifications. The voltage V_{pv} is assumed to be constant and its power is varied according to the variation in current. The main advantage of using high frequency transformer is that it will reduce the transformer size and cost. The peak value of duty cycle is obtained at wt=90^o. The whole designing of main inverter system is done in such a way that to reduce the switching losses and enhance the efficiency. The inductor is designed at cut off frequency. The output capacitor is designed in such a way that to feed the output when the main switch M1 is turned on.

III. STEADY STATE ANALYSIS

For each switching cycle the operating modes of fly back inverter with high frequency operation may varies and is assumed to be a function in quasi-steady state. The operating modes of proposed inverter are discussed here.

A. CCM Operation

For a particular switching period the PV panel is directly connected to the primary winding of transformer and M1 is on. When the fly back micro inverter is operating under CCM alone the switching losses will be high.

Voltage across primary winding is given by the equation

$$Vp = Lm\frac{\Delta I}{DTs} \qquad (1)$$

Where

V_p =voltage across primary winding
Lm=magnetizing inductance
ΔI= change in current
Ts=switching time

The voltage across primary winding during main switch is off is given by the equation

$$Vp = \frac{Lm\,\Delta I}{(1-D)DTs} \qquad (2)$$

Where

D= Duty cycle.

The waveforms for switching pulses and current and voltage through primary winding during CCM are shown below.

B. DCM Operation

The current will be discontinuous during DCM operation .If the load is very light, very small amount of energy needs to be input to the circuit in each switching cycle. This is achieved by keeping the on time is low , resulting in low duty cycle. Within this small on time of current build up in primary winding. The off time of switch is large during this time interval .For better control DCM is preferred.

$$Dcm = 2\sqrt{\left[Ipv\,Lm\frac{Fs}{Vp}\right]}\,sinwt \qquad (3)$$

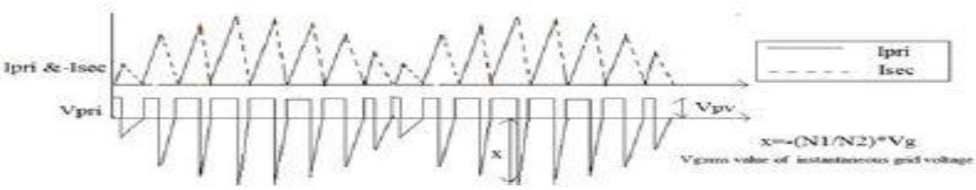

Fig 3. Theoretical waveforms of current and voltage waveforms of the transformer in CCM mode

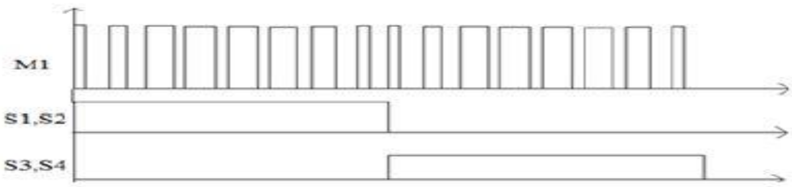

Fig 4. Theoretical waveforms of switching pulses the transformer in CCM mode

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C. *BCM Operation*

The peak value of duty cycle of CCM and DCM are equating to get the required boundary conduction mode of operation. The critical value of magnetizing inductance is given by the equation.

D. Comparison of different modes

The peak value of current may distracted during CCM mode of operation. A complex algorithm is required for CCM operation. Because it needs to sense the current. During DCM switching frequency remains constant but the high frequency transformer is fully demagnetised before the next switching cycle. So there is a probability of inverter to enter into CCM and thus short circuit the system. When the power level is higher than that of a particular limit we are adopting CCM mode of operation. The DCM operation is preferred when the irradiance level is low. Due to the incomplete demagnetization of energy in transformer core in each switching cycle, the current waveform gets distorted from the sinusoidal shape near the peak instants and there can be voltage spikes across the windings in CCM. Therefore we are using a fly back inverter with mppt control. By using mppt control individual conduction mode has no significance thus we can avoid the limitation of integrating two modes of operation of fly back inverter. The INC method of mppt control makes the control algorithm simpler.

E. Mppt control

The major principle of mppt is to extract maximum available power from PV module by making them operating at the most efficient voltage called maximum power point. Mppt checks output of PV module, compares to grid voltage then fixes what is the best power that PV module can produce to change the grid voltage and convert into the best voltage to get maximum current. Here we are using INC method of mppt control. This algorithm compares the incremental conductance to the instantaneous conductance in PV system. Depending on the result it increases or decreases voltage until the maximum power point is reached. Unlike with P&O algorithm, voltage remains constant once maximum point is reached. The algorithm for INC method is shown below.

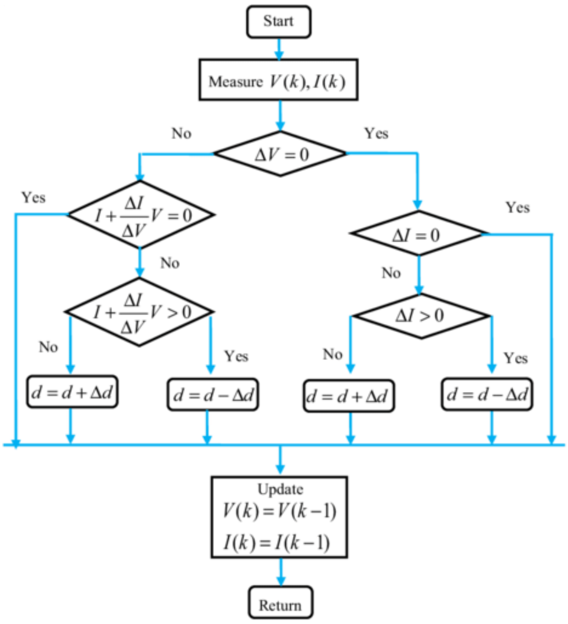

Fig 5.INC Algorithm

IV. SIMULATION RESULTS AND COMPARISON

The simulation of fly back inverter with center tapped configuration as well as two winding configuration was done in MATLAB environment and the results are compared. The INC MPPT technique is used to obtain maximum power from the PV panel. The simulink models of both configurations are shown below. The main disadvantage of using center tapped configuration is that it may produce more asymmetrical waveform if there is any change in center tapped point. That is the reason why we are go along with two winding transformer configuration, also the integration of two

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modes of operation at different irradiance level is difficult and current losses will be high. The voltage stress across each switch will also be reduced and increase the transformer utilisation factor. The output voltage waveform may contain initial transients. The current waveform is also shown in figure 13. The output voltage is 230 V and is supplied to the grid. The THD of proposed inverter can be reduced to 1.09% as compared to 1.72% in normal center tapped configuration. The individual DCM as well as BCM operation of fly back inverter has THD of 1.72% and 1.2% respectively. In order to improve the power quality, fly back inverter with mppt control is proposed. At low irradiance level the control algorithm is written in such a way that to enter the system into DCM and at high irradiance level it may enter into BCM.

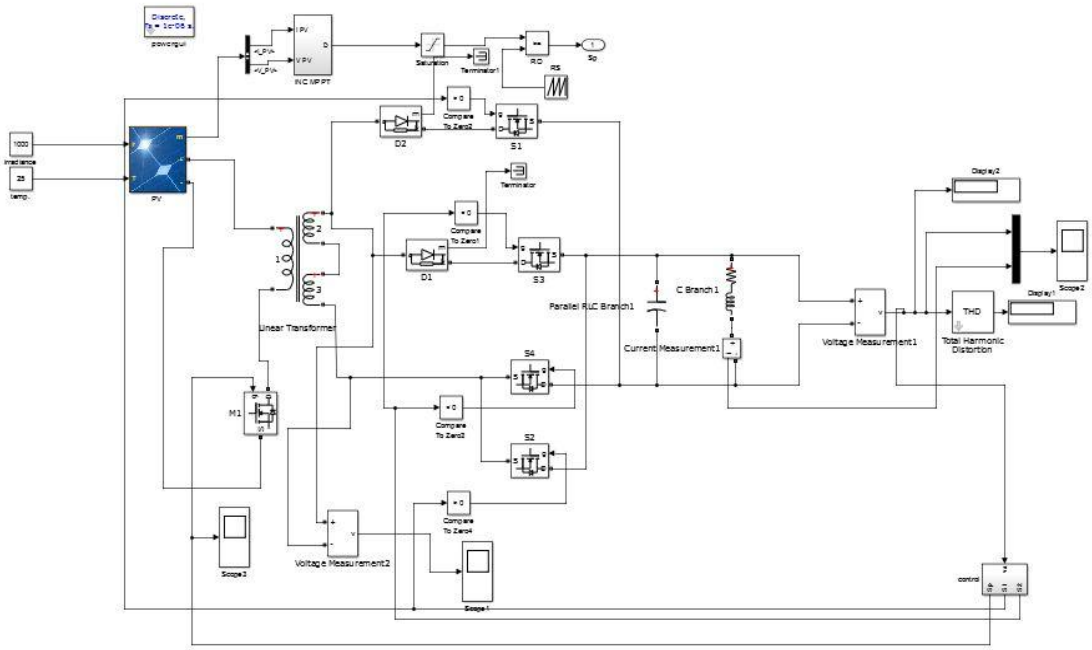

Fig 6a. Simulink model of proposed inverter with two winding configuration

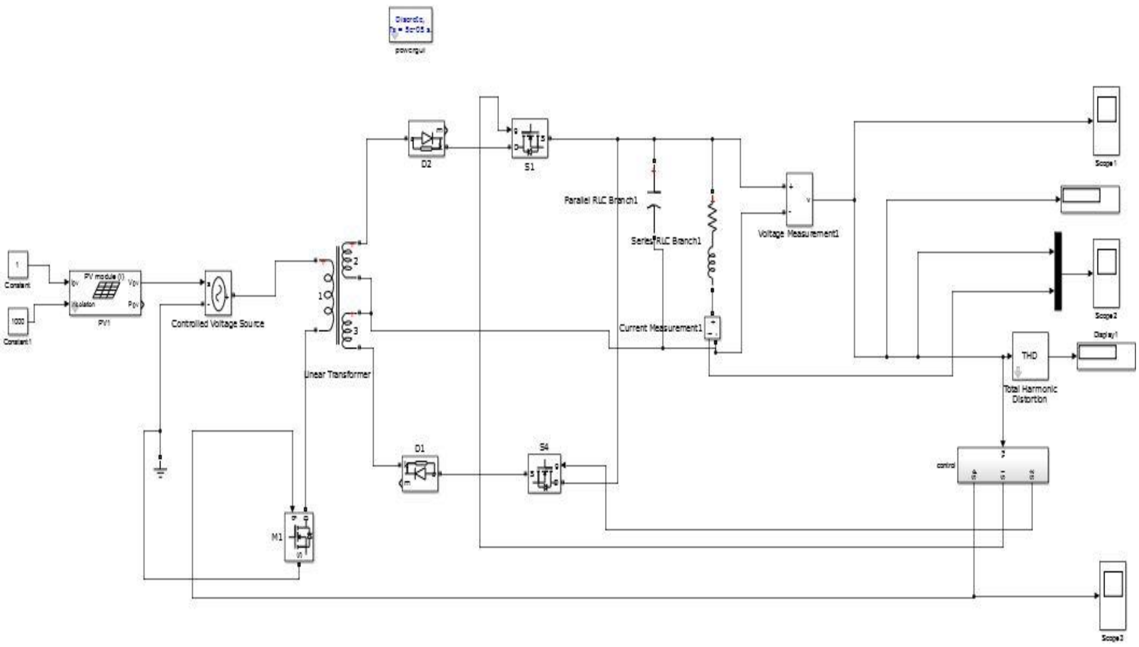

Fig 6b.Simulink model of flyback inverter with center tapped configuration

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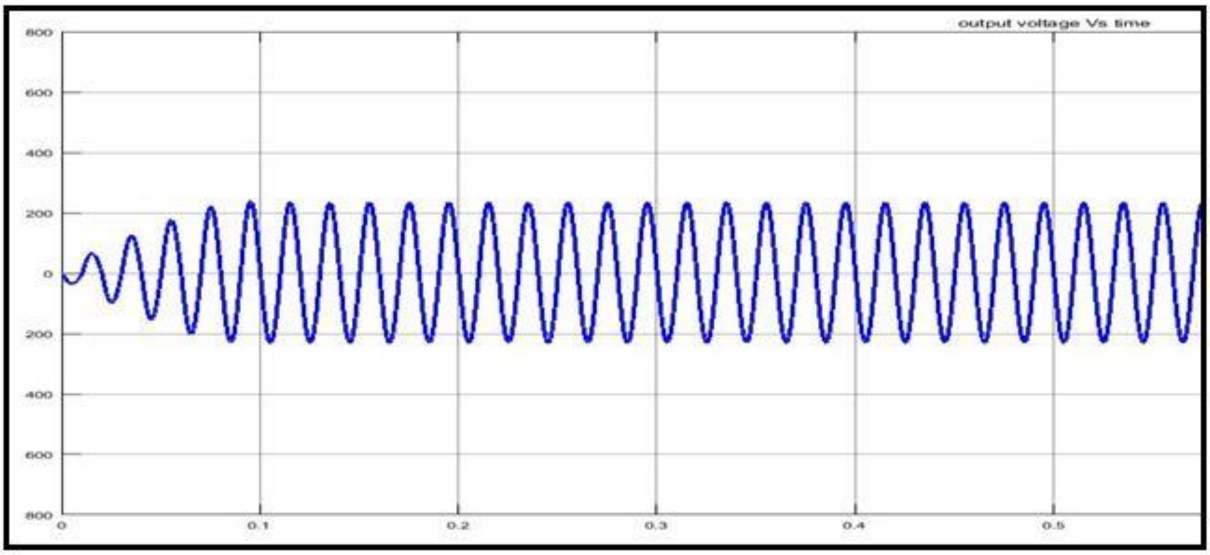

Fig 6c.Wave form of output voltage

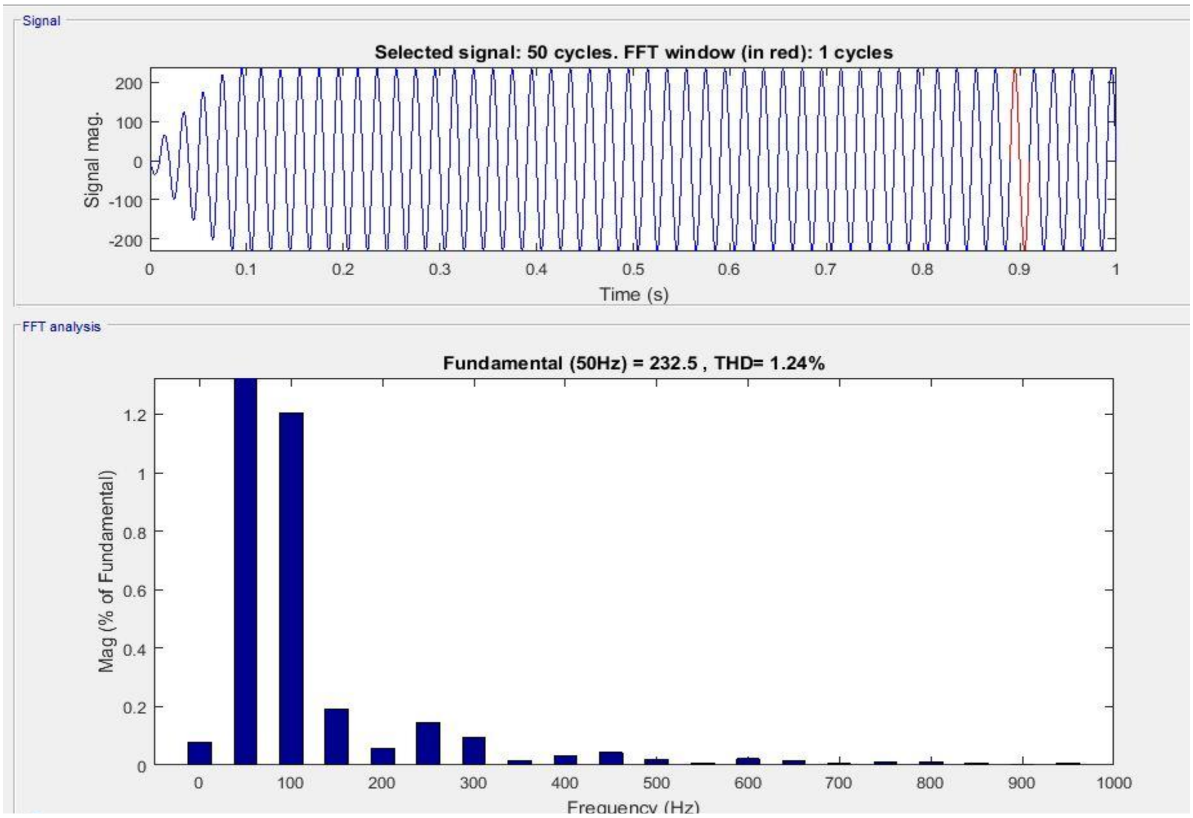

Fig 6d. Waveform of output voltage and the harmonic spectrum

V. CONCLUSION

In this paper a flyback micro inverter with two winding transformer configuration and mppt control is proposed. The comparison of flyback inverter with different configuration is also studied. The proposed topology provides better power quality by reducing the THD to 1.09% as compared to other topologies. The presence of Flyback transformer provides necessary isolation and the problems of TCO corrosion and leakage current is avoided by double grounding. Since single primary and secondary is used in the Flyback transformer, transformer Utilisation Factor (TUF) is improved which increases efficiency.

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