iJRASET

International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IV **Month of publication:** April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4778

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Analysis and Implementation of Single Phase PV based Micro Inverter with an Optimal Controller

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Abstract: Adaption of non-conventional energy sources for the power generation has a key role which leads to green environment. The problem that arises with the Consideration of PV based solar panel is the existence of common mode currents. However, this issue can be resolved by the consideration of galvanic isolation between the PV panel and the load. Hence flyback converter is considered. For the extraction of maximum power from the PV panel, P&O MPPT algorithm is considered. In this paper the work is carried out with the Interleaved flyback converter with pseudo DC link Inverter, which have more advantages. The results are analysed through the simulation in MATLAB 2016A.In this work 40 Watt Solar panel is considered.
Keywords: Interleaved Flyback convertert; Pseudo DC Link; MPPT

I. INTRODUCTION

Now a days the demand for electricity is increasing tremendously in the world. Hence to meet this huge demand the existing sources of power generation are not sufficient as they could extinct soon, if the usage is more. Moreover, the sources like thermal, diesel power plants causes environmental pollution. Hence to overcome this problem the adoption of non conventional energy sources is to be involved. Hence Photovoltaic based systems has a vital role in the field of engineering. The DC Power generated from the PV system is converted into AC power by the power electronic converter called Inverter with the involvement of DC-DC converter. Now the existing types of grid connected Inverters are three which are the centralized inverters, the string inverters and the Module Integrated Converter (MIC). Among these, the MIC system offers “plug and play” concept and greatly optimizes the energy yield. Among these the features of MIC are best for the grid connected as there is opportunity for the change of Modules, if it is perforated. DC Cabling requirement is not needed and mismatch losses between PV Modules can also be reduced. The classification of the MIC topologies is done based on the DC link which are as follows.

1) MIC with DC Link
2) MIC with Pseudo DC link
3) MIC without DC link

The equations regarding the modeling of the Photovoltaic model is explained in[1].MPPT has the vital role in the PV systems and the implementation of Perturb and Observe method is simple [2]. The explanation of various topologies of inverters based on DC link is categorized as three types which are MIC with DC link, pseudo DC link and without DC link inverter[3].The Pseudo DC link configuration has an advantage of switch strategy of unfolder stage which will be operated at 50 Hz instead of high frequencies(PWM inverter),the principle adopted for this purpose is Zero Crossing Detector[4]. Flyback converter offers more advantages in DCM and in BCM rather than in CCM[5].The control strategy involved in Continuous Mode of operation of flyback converter is difficult as it involves RHP zero [6]. The control strategy and operation of flyback converter in DCM involves less complexity and rather easy than CCM[7]. Analysis and the implementation of grid connected inverter with interleaved flyback converter is clearly explained by Microchip in [8].To optimize the error function in an Interleaved micro inverter, a new method is proposed which is Finite Gradient Descent Method[9].Generally Flyback Converters are employed for the rating below 200W effectively. But in [10], by modifying the transformer construction it is effectively employed in the grid connected inverter for high power as well(2000W). Single stage inverter achieves more efficiency rather than two stage inverter[11].T/4 delay Phase Locked Loop has key role in single phase systems[12].

II. PRINCIPLE OF OPERATION

The design is done for the power rating of 40 Watts. Hence the output voltage requirement is 220 V RMS and 50Hz and the output current is 0.115A(maximum).As the panel gives 17.7V at STC (1000 W/m^2).The voltage is to be stepped using DC-DC converter

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.Hence for this purpose Flyback converter is selected as it has more advantages like simple structure and low cost, besides interleaving. Apart from the conventional PWM inverter with DC link, Pseudo DC link is preferred and the switching strategy to the inverter switches is by the principle of detection of Zero Crossing.

A. *Single stage and Two stage control*

In two stage conversion, the first stage includes the boosting of PV voltage of array and track the maximum power from the array, then the second stage inverts DC power to AC power as shown in the figure below.

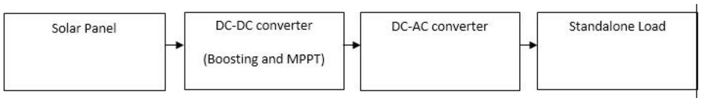

Fig 1.Two Stage Converter

The drawbacks of the above mentioned configuration are high cost, larger in size and lower reliability. Hence we prefer single stage configuration. In single stage configuration, the boosting, MPPT and Inverting occurs simultaneously as shown below.

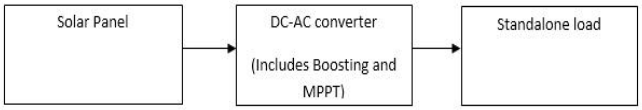

Fig 2.Single Stage Converter

From the above analysis, single stage has more benefits and
the work is carriedout with this configuration. Further, interleaving of flyback stages facilitates the less burden over switches as the two switches share the power equally. This can be facilitated by the provision of 180^0 phase shift between the switching pulses. The detailed analysis of interleaving is discussed in the following section.

B. *Principle of Interleaving*

Interleaving offers many benefits such as

1) Reduction in primary peak currents of transformer,
2) Ripple at the output is also reduced.
3) Filter size can be reduced
4) Reduced RMS input currents which leads to the cost of capacitor less expensive.

III. BLOCK DIAGRAM

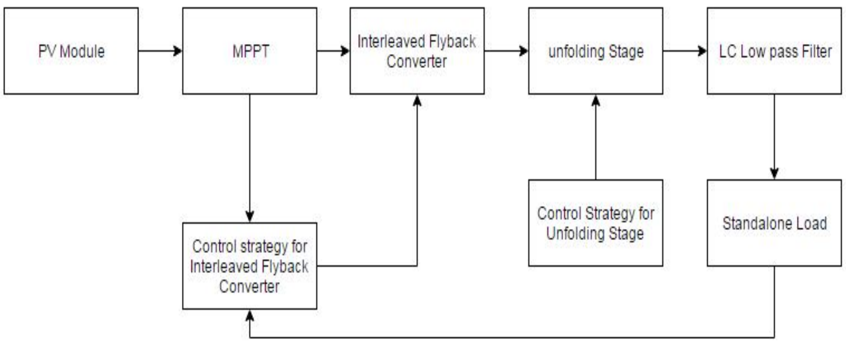

Fig 3. Block diagram

PV Modeling

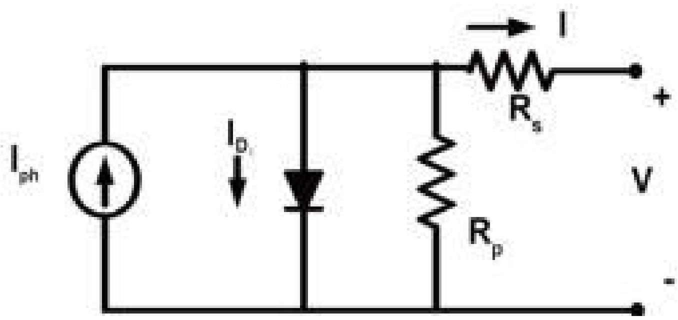

Fig 4. PV Model

$$I = I_{ph} - I_0\left[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1\right] - \frac{V + IR_s}{R_p} \qquad (1)$$

$$I_{ph} = \frac{G}{G_n}\left[I_{pvn} + K1(T - T_n)\right] \qquad (2)$$

$$I_0 = I_{on}\left(\frac{T_n}{T}\right)^3 \exp\left[\frac{QE_g}{NK}\left(\frac{1}{T_n} - \frac{1}{T}\right)\right] \qquad (3)$$

$$I_{on} = \frac{I_{scn}}{\exp\left(\frac{V_{oc}}{NV_{Tn}}\right) - 1} \qquad (4)$$

$$V_T = \frac{KT}{q} \qquad (5)$$

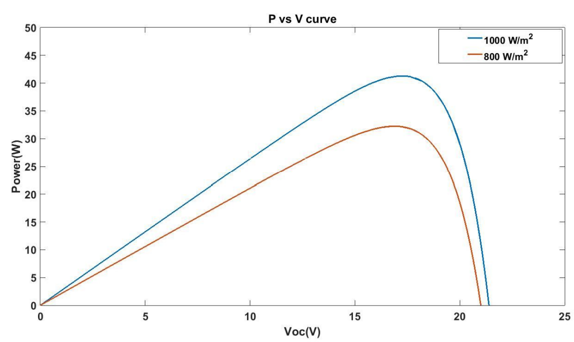

Fig 5.V vs P curve at different Irradiation

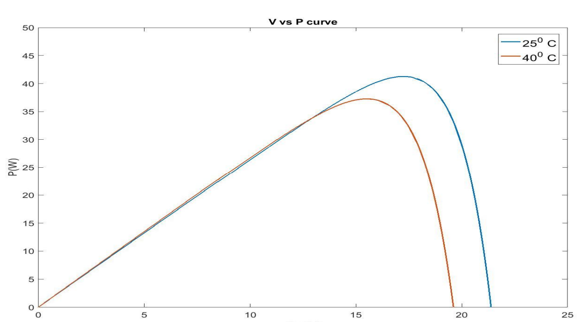

Fig 6. V vs P curve at different temperature

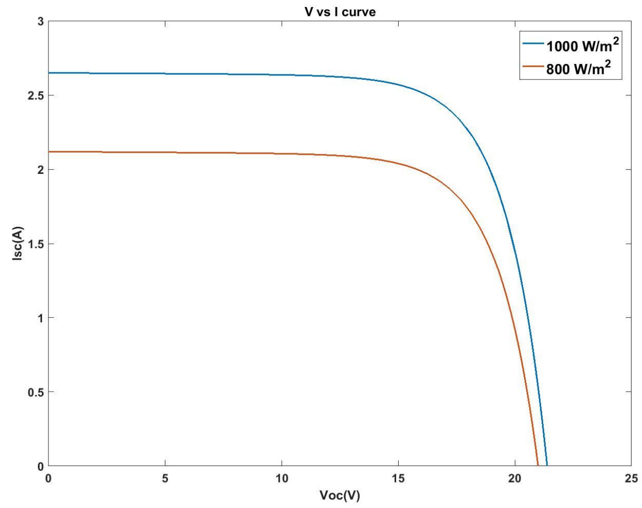

Fig 7.V vs I at different Irradiation

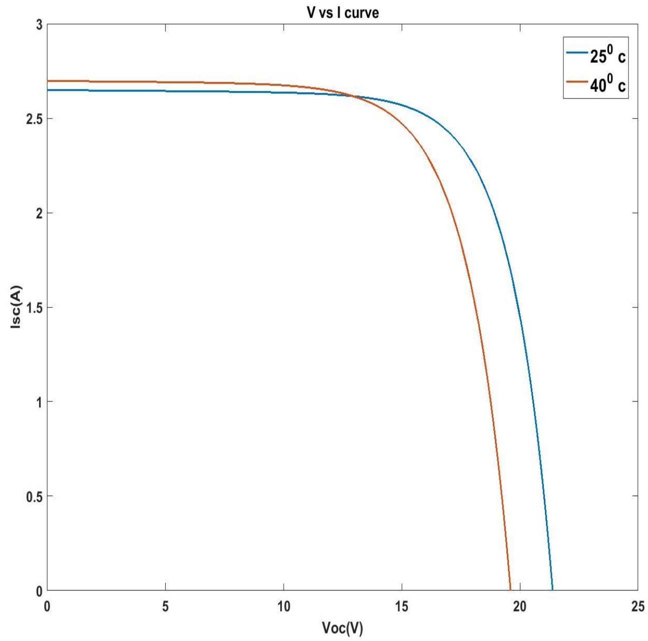

Fig 8.V vs I at different temperature

From the above figures it is observed that current and power of the PV module increases with the increase in solar irradiance at constant temperature.It is also observed that power and voltage is decreased as the temperature is increased for constant solar irradiation.

A. MPPT

Irrespective of changing weather conditions i.e solar irradiance and temperature,it is essential to track the maximum power from the solar PV panel.Hence PV systems make use of a maximum power point tracking (MPPT) controller.For the maximumpower transfer to the load from the solar panel,the impedance matching is necessary. So by changing the duty ratio of the DC-DC converter,impedance can be changed and at the particular impedance or duty ratio the operating point will be maintained at the Maximum Power Point. Many MPPT methods are proposed.In this work Perturb and Observe MPPT method is selected because of simplicity in implementation

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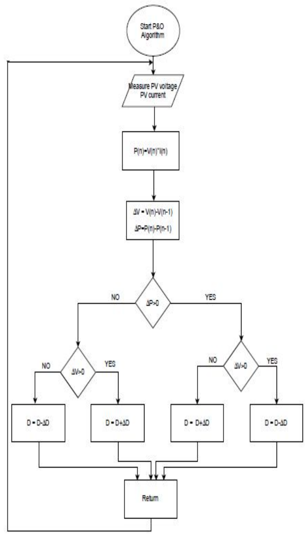

Fig 9. Flow Chart of MPPT (P&O Algorithm)

The effective impedance seen from the solar panel is as follows
For flyback converter

$$R_e = R_L \left(\frac{1-D}{D}\right)^2 \left(\frac{N_1}{N_2}\right)^2 \qquad (6)$$

Re _ Effective impedance seen from the panel
D _ Duty ratio corresponding to the impedance Matching
N_1/N_2 _ Transformer Turns ratio

RL – Load Resistance

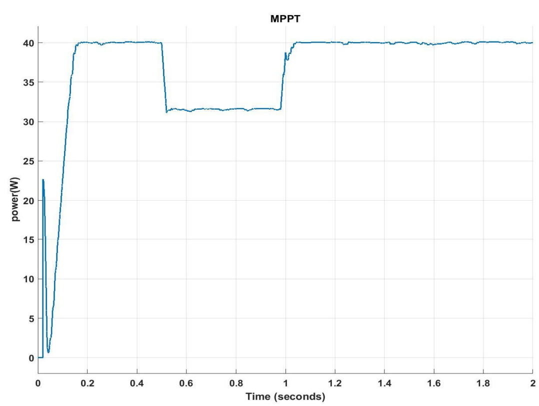

Fig 10. MPPT plot

C. Analysis of converter

When the switch is turned on the V_{pv} is applied to the primary of the transformer and hence the primary current flows in the transformer which is the magnetizing current and when it is turned off ,the flyback transformer primary voltage become negative and scaled by the turn ratio.The mode of operation selected is Discontinuous Conduction Mode,as it has some advantages compared to Continuous Conduction Mode like very fast dynamic response , less turnon losses and transformer size is less as well.

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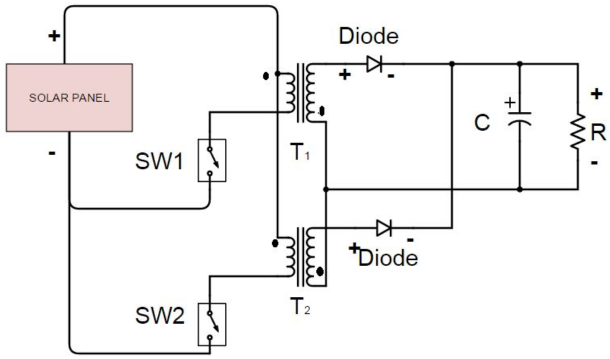

Fig 11. Interleaved Fly back Converter

D .Hardware Realization

As it was mentioned earlier that the phase shift for the switching pulses of two switches for interleaved flyback converter adopted is about 180^0,the programing is done in PIC microcontroller using PIC16F877A with the fixed duty ratio of 0.3.

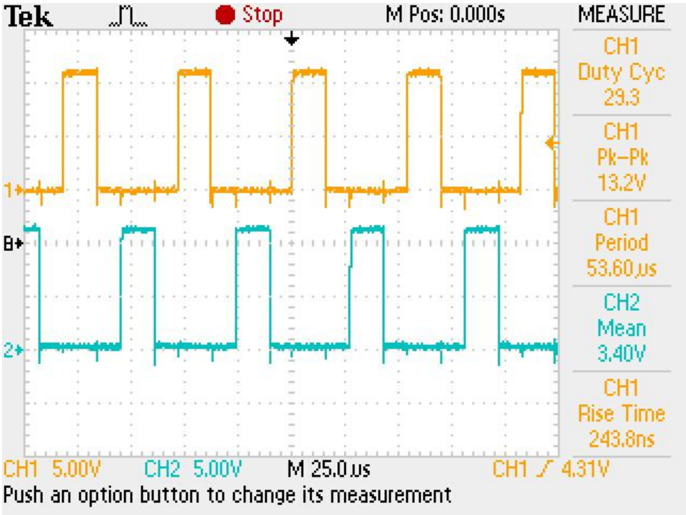

Fig 12. Switching pulses for Interleaved flyback converter

The output voltage of the converter observed at 9 Volts is around 41 V.

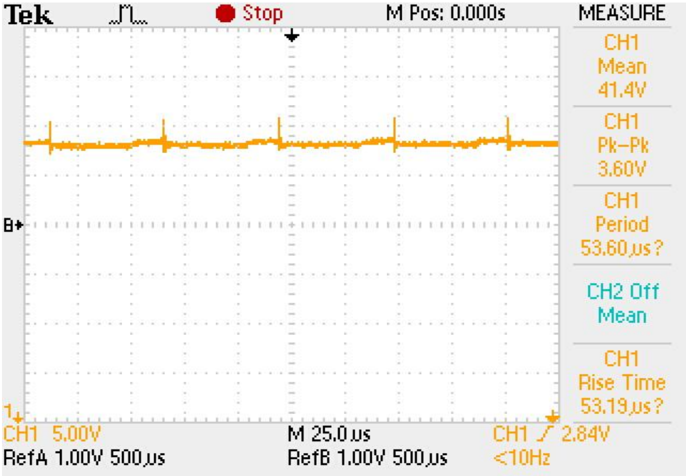

Fig 13. Output Voltage of Converter

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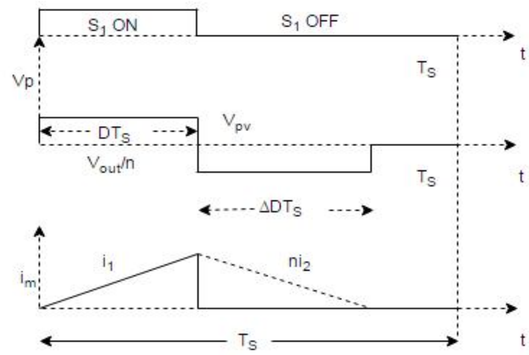

Fig 14. Switching Strategy

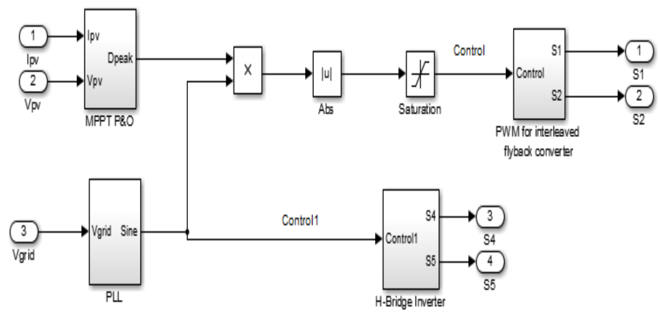

Fig 15.Control Strategy for Flyback Converter

E.Phase Locked Loop

In this work T/4 delay Phase Locked Loop is employed. The load voltage is taken as α component and β is taken as phase shift of π/2 radians with respect to fundamental frequency of the input voltage. As the phenomenon of interleaving is used 180^0 phase shift between the gate pulses is maintained.Thus the park's transform is used to detect the phase error.Here Vd can be controlled to zero by using PI controller,and then the phase of the input signal is locked.This is the easiest method that can be used to extract the phase angle in single phase application.

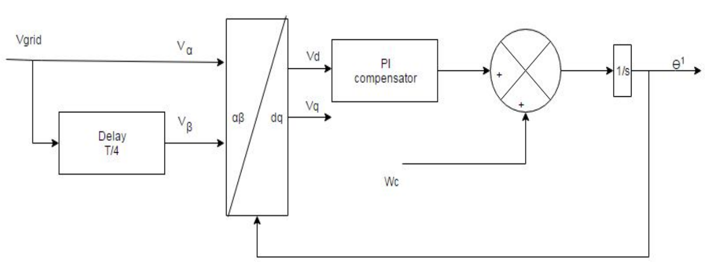

Fig 16.T/4 Delay PLL

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F. Unfolding stage and polarity detector

The unfolding stage unfolds the rectified sinusoid into alternating sinusoidal voltage.Hence the switching scheme involved for the switches of unfolding inverter is zero crossing detection (50Hz) instead of Pulse width modulation.The logic is given below

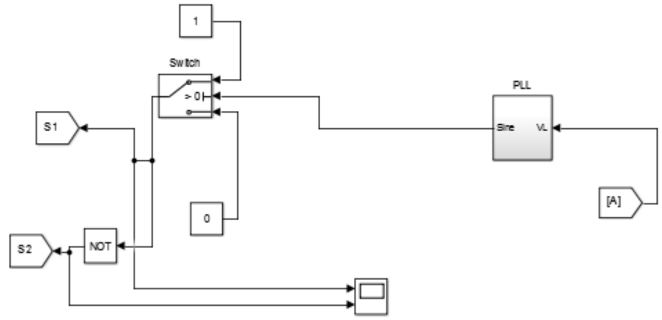

Fig 17. Logic of Zero Crossing Detector

G. Specifications

Parameter	**Value**
Switching Frequency	20KHz
Magnetizing Inductance	47μH
Maximum Duty Ratio	0.5
Decoupling Capacitor	2mF
Filter Inductance	90mH
Filter Capacitance	88μF
Load Resistance	2757Ω
Maximum Power	40 Watts

TABLE1 SPECIFICATIONS

H. Output of H-Bridge Inverter

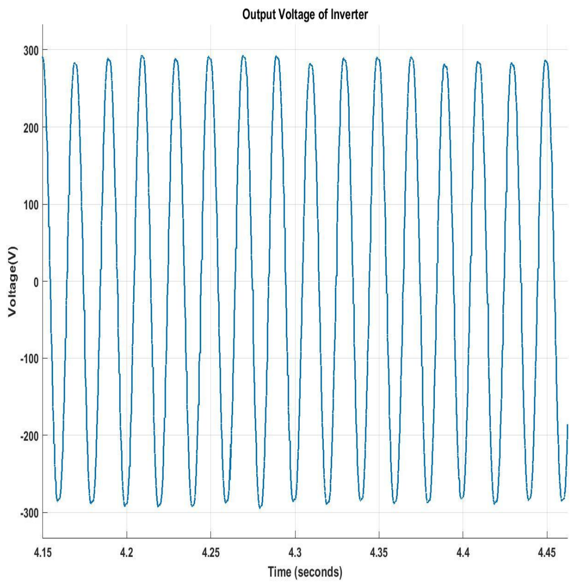

Fig 18. Output Voltage

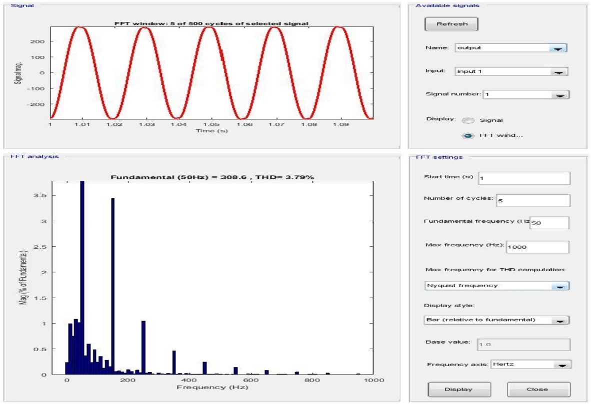

Fig 19.THD of Inverter Output

III. RESULTS AND SIMULATION ANALYSIS

From the MPPT Plot,it is understood that the Perturb and observe algorithm tracks the Maximum power and the perturbation is given at 0.5s in the simulation and hence the MPPT algorithm acts correspondingly.As the principle of interleaving is adopted the ripples in the output voltage is decreased.The problem of DC voltage regulation at DC bus is eliminated as the DC link Capacitor is not included.As the configuration of the inverter is pseudo DC link inverter,instead of SPWM,Zerocrossing detector is used for the switches to the inverter which has been clearly mentioned,which significantly decreases the witching losses of inverter switches.

IV. FURTHER WORK

The hybrid multilevel inverter offers improved output powerquality and also switching losses can also be effectively reduced.

V. CONCLUSION

Hence the model of Pseudo DC link inverter with interleaved DC-DC flyback converter is simulated and the corresponding results are presented.The advantages that are observed in this topology are ripple is less on the output voltage,DC bus voltage balancing problem is eliminated,inverter switching losses are also reduced as the principle used is Zero Crossing Detection instead of Sinusoidal Pulse Width Modulation.Also,the THD observed in this topology is around 3.78% ,which indicates more efficient.

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