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High Power Interleaved Flyback Inverter for PV Applications

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Abstract- **The impact of solar power is one of the thriving concerns in the world today. The proper utilization of solar energy in modern life style opens a wide path to new technologies. This paper deals with simulation and analysis, design, of an isolated grid-connected inverter for photovoltaic (PV) applications. The system uses an interleaved flyback converter followed by a single phase inverter. Flyback topology works in discontinuous current (DCM) mode of operation .The aim of this paper is to monitor PV module effectively and operate flyback converter at high power with good performance which is difficult to implement. The interleaved inverter system rated at 1kw gives an added benefit of reduced size of passive filtering element and reduces the overall cost. A simulation model of the proposed inverter system is developed and the design is verified for good performance based on the simulation results. Maximum power tracking of the solar energy is facilitated through maximum power point tracking (MPPT) for each PV panel with reduced maintenance cost and time.**

Keywords: **Flyback converter, MPPT, harmonics, interleaved converters, photovoltaic phenomena.**

I. INTRODUCTION

The solar energy is a renewable free source of energy that is sustainable and totally inexhaustible which contributes an important role in the energy market of the world. The main benefit of solar energy is that it does not produce any pollutants and is one of the cleanest sources of energy. Many research works are being carried on this field with sustainable world as a concern.This paper demonstrates simulation of different stages involving in a PV system. The primary objective is to contribute an innovative and improved system to monitor the photo voltaic (PV) panels by using flyback technology for high power applications. The good performance flyback system is also added on to our primary research contribution. The inverter system developed can be a low-cost system compared to the commercial isolated grid-connected PV inverters available in the market. The core motivations of this paper are to develop an efficient and economic system with simple structure of flyback topology and easy power flow with high power quality.

The solar energy can be harvested effectively through this method since there is a dedicated maximum power point tracker for the PV system. Besides the performance improvements, it is shown that the proposed approach allows possible reduction of hardware costs. The selection of operation mode is another important factor. The mode of operation for the converter is discontinuous current mode (DCM) which has several advantages summarized as follows:

- Provides very fast dynamic response.
- No reverse recovery problem.
- No turn on losses.
- Small size of the transformer.
- Easy control.

The main disadvantages of this mode is higher form factor(high RMS to mean ratio) compared to continuous current mode(CCM) leads to more power losses .Device paralleling is the solution, we provide interleaving which reduces the current peak value with high discontinuity. This discontinuity is overcome by connecting all cells together at a common point.

The remaining sections of this paper are organized as follows. Section II describes the photovoltaic cell and designing. Section III presents MPPT and the selected method (algorithm). Section IV describes Converter topology. The sections V and VI give the overall simulation and result analysis. Finally, section VII provides the conclusion.

II. PHOTOVOLTAIC CELL

Photovoltaic cells convert solar radiation into DC. A PV cell is the building block of a solar panel and it can be formed by the series and parallel connection of many solar cells.

Single diode model of the solar cell is shown in fig1.

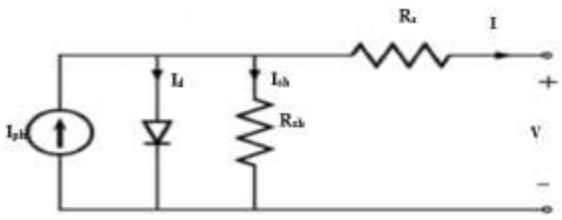


Fig 1: PV cell equivalent circuit

An ideal solar cell can be modelled by a current source in parallel with a diode, in practice no solar cell is ideal and so a shunt resistance and a series resistance component are added to the model. The characteristic equation has a common application such as nonlinear regression to extract the values of respective parameters in equivalent circuit. It is on the basis of their combined effects on solar cell behaviour. The light generated current and reverse saturation current get multiplied by the N_p.

Equation governing the voltage current characteristic of a solar cell is given as,

$$I = N_p I_{ph} - N_p I_s \{\exp q(v + IR_{sm})/N_s K T_c A) - 1\}$$

Where,
q: Electron charge = 1.6×10^{-19}C
A: Ideality Factor = 1.6
k: Boltzmann Constant = 1.3805×10^{-23}J/K
Is : Dark current/cell saturation current
I_{ph}: Photoncurrent/light generated current
R_{sm}: Solar cell series resistance (Ω)

III. MAXIMUM POWER POINT TRACKING

The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power depends on several factors including environmental conditions such as solar radiation/irradiance, ambient temperature and solar cell temperature. There are several methods employed for tracking maximum power among which **Perturb and Observe** method is implemented in this paper.

A. Perturb and Observe MPPT Algorithm.

P&O algorithm is also called Hill climbing method. It is the most commonly used MPPT algorithm due to its ease of implementation. In this method the controller adjusts the voltagefrom the array by a small amount and measures power. Ifthe power increases, further adjustments in that direction are tried until power no longer increases.The duty cycle is adjusted directly in the algorithm.P&O algorithm is based on the fact that, the derivative of power as function of voltage is zero at MPPT. The Fig. 2 shows the flowchart of the P&O algorithm.

The output voltage waveform of PV system with MPPT(P&O) algorithm is represented in fig 5. The adaptive P&O technique is based on duty cycle modulation for conventional pulse width modulation converters. Therefore for tracking the maximum power point, suitable MPPT algorithm is used.

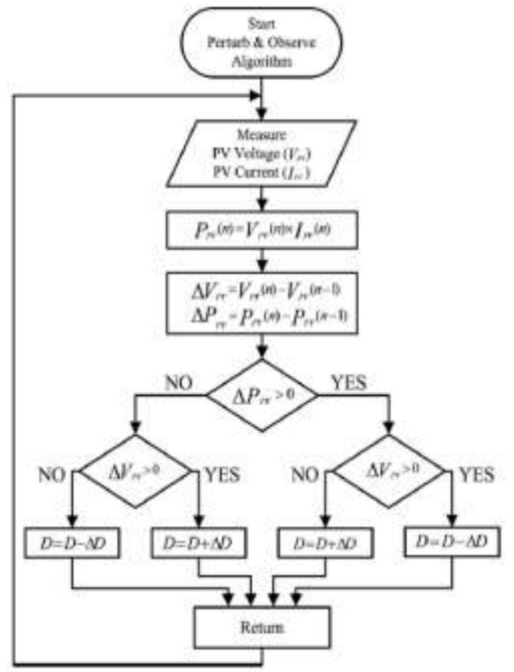


Fig 2: Flow Chart of P&O Algorithm.

IV. INTERLEAVED FLYBACK CONVERTER

The fly back converter is an isolated power converter. It is equivalent to a buck-boost converter and used in both AC/DC and DC/DC conversion with galvanic isolation between the input and outputs .It is a lowest cost converter among many isolated topology since it use only least number of component .In this flyback topology the energy storing inductor is combined with the transformer.

Normally in other type of isolated topologies, the energy storing inductor and transformer are separate elements since the inductor is responsible for energy storage and transformer for energy transfer over galvanic isolation .Thus the combination of these, eliminate the bulky and costly energy storing Inductor and thus lead to reduction in cost and size of converter. It is practically a challenge to implementa transformer with large energy storing capability.

A high power fly back converter design needs large air gap in transformer which reduces the magnetizing inductance. As a result, large leakage flux with poor coupling and low energy transfer efficiency occurs.Due to this reason, the flyback converters are generally not designed for high power applications. Through interleaving of flyback stages, it can be used for high power applications. The benefit of interleaving is that the frequency of the ripple components of the waveforms are increased in proportion to the number of interleaved cells. This feature facilitates the easy filtering of the ripple components.

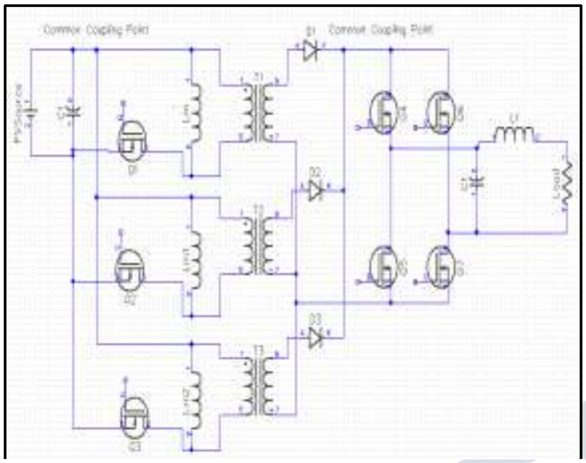


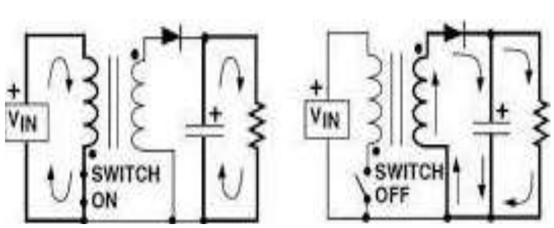
Fig.3 Circuit schematic of the proposed flyback inverter system based on three-cell interleaved converter topology

a. Modes of operation

The flyback converter operates in two modes such as Mode1and Mode 2.

Mode1: When the flyback switchis turned on,current flows from the PV source into the magnetising inductance of the flyback transformer. Thus it stores enough energy in the form of magnetic field to replenish the load during the time the switch opens.During this mode of operation no current flows to the output due to the position of the secondary side diode. Thus energy to the grid is supplied by the filter. Mode 1 operation is illustrated in fig 4(a).

Mode 2: In this mode of operation, the flyback switch is turned off. The energy stored in the magnetising inductance is transferred into the grid side in the form of current. It is illustrated in fig.4 (b)



(a) (b)

Fig.4 Operating modes of Flyback converter. (a)Mode 1and (b) Mode 2 operations.

b. ***Flyback transformer and Design.***

The flyback transformers have to store large amount of energy and then transfer it to the output through magnetic coupling at every switching cycle.When inductors are designed for the discontinuous mode, with significant core loss, total loss is at a broad minimum when core and winding losses are approximately equal. In order to store and return energy to the circuit efficiently and with minimal physical size, a small non-magnetic gap is required in series with a high permeability magnetic core material. In ferrite or laminated metal alloy cores, the required gap is physically discrete.

Suitable core material appropriate for the desired frequency and inductor current mode are selected. Ferrite is usually the best choice for inductors designed to operate in the discontinuous mode at frequencies above 50Khz.

The magnetizing inductance of the flyback transformer *Lm* is determined under nominal conditions from the table provided.

Table I

Design parameters	Specifications
Total maximum power from PV panel(W)	1000
PV voltage(V)	88
Duty ratio information(D_{peak})	0.3333
No. of interleaving cells(n)	3
Grid voltage(V)	230
Turns ratio(N)	1:10
Magnetic inductance(L_m)	8

$$L=\frac{\mu_0 N^2 A_g}{L_g} * 10^{-2}$$

$$l_g=\frac{\mu_0 N^2 A_g}{2} * 10^4$$

$$L=N^2 A_L \text{ nH}$$

$$n=\frac{V_{in}}{Vo} * \frac{D}{1-D}$$

$$D=\frac{nV_0}{V_{in+nV_0}}$$

$$n= V_{grid}\,(1- D_{peak})/V_{PV}\,D_{peak}$$

$$i_g = N^2 \mu A_{core} / L_m$$

μ -Permeability of Core

A_{core}-Area of Core.

L: inductance in Henry

l_g: discrete gap length

A_g: corrected gap area
D:duty ratio
N:transformer turns ratio

V. OVERALL SIMULATION.

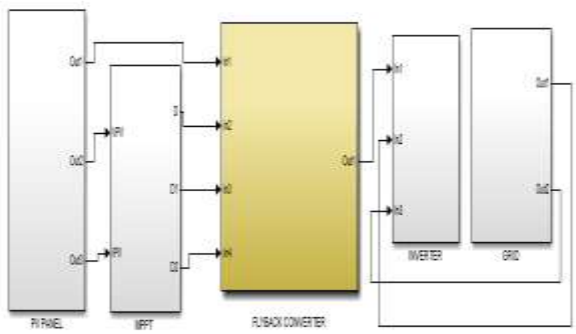


Fig.4 Overall Simulation

VI. RESULT ANALYSIS.

The proposed model is simulated by MATLAB Simulink 2013 and the result of the simulation are obtained as follows.

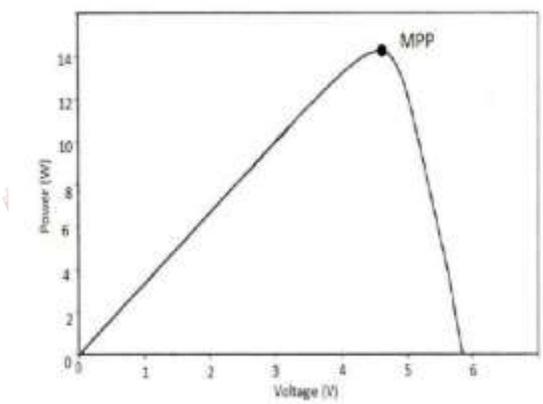


Fig .5 P V characteristics.

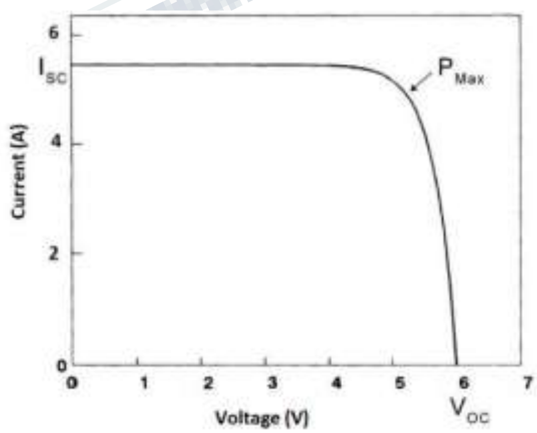


Fig. 6 V Icharacteristics.

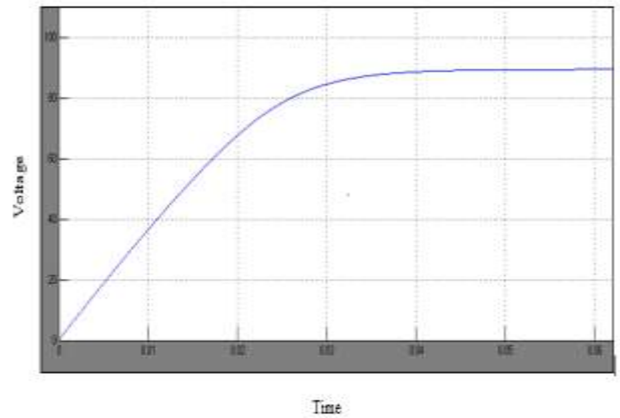


Fig. 7 Output Voltage Waveform of PV

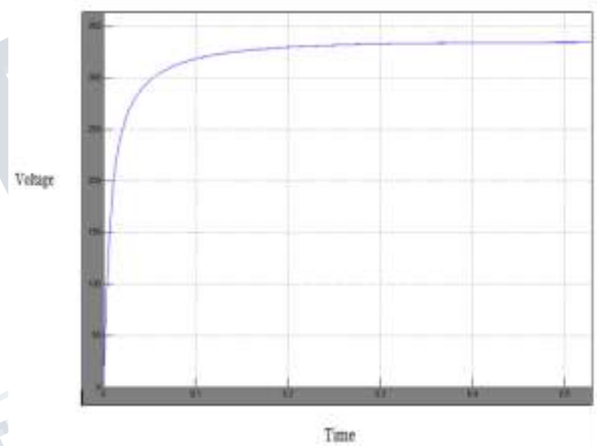


Fig. 8 Output Voltage Waveform of Flyback Converter

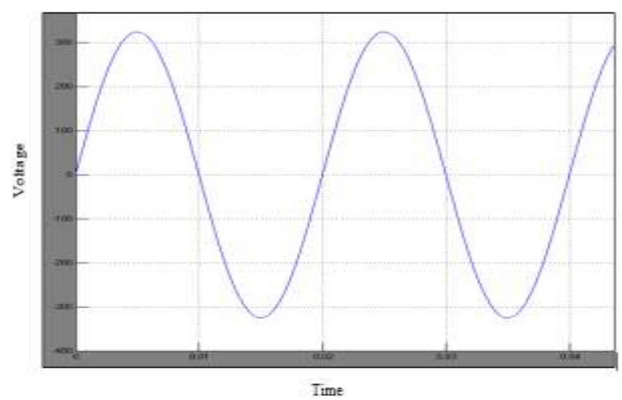


Fig 9. Inverter Output Voltage Waveform

VII. CONCLUSION

Interleaved flyback converter topology is simulatedeffectively over a central PV system rated at 1 KW working with an efficient MPPT algorithm. The inverter current, withhigh power quality (PQ) and low total harmonic distortionare obtained.Interleaving of flyback converter improves filtering with the use of reduced filtering elements. Theeconomic concerns are covered through the simple structure of interleaved flyback converter than conventional system.

REFERENCES

[1] Bunyamin Tamyurek, *Member*, *IEEE*, and Bilgehan Kirimer "*An Interleaved High-Power Flyback Inverter for Photovoltaic Applications*."; IEEE Trans June 2015.

[2] E.Roman,R.Alonso,P.Ibanez,D.Goitia, S.Elorduizapataraietexe;*"Intelligent PV module for Grid connected PV Systems";* Industrial Electronics IEEE Trans, Issue 4,June 2006.

[3] N.Kasa, T.lida and L.Chen,"*Flyback Inverter Controlled By Sensorless current MPPT for Photo Voltaic Power System*" IEEE Trans.Ind.Electron,Vol.52,Aug.2005.

[4] WongsakornLimsiri, PairoteSirinamaratana and EkachaiLeelarasmee "*Development of PLC Circuit for Solar farm Monitoring "; IEEC* 2014.

