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Analysis and Design of Fly-back Micro-Inverter for PV Applications

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Abstract— In recent days, the use of renewable energy sources for power generation has gained the vital importance over the conventional energy sources. In this paper, analysis and design of single phase fly-back micro-inverter for solar photovoltaic applications is presented. Fly-back inverter is operated in Continuous conduction mode in order to feed pure sinusoidal current to the loads connected in a stand-alone mode and to inject in to the grid in case of utility connected system. Here, a high frequency fly-back transformer is used to transform the power extracted from solar energy which is in direct current form in to an alternating form, which is then rectified using a diode and is inverted using single phase PWM inverter to feed it to the load. The simulation study of system is done using PSIM software and the results are presented.

Keywords- *Micro inverter; fly-back transformer; single phase inverter.*

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I. INTRODUCTION

Seeing the existing energy scenario, the entire world is moving towards the generation of electrical power from the renewable energy sources like solar PV, wind, fuel cells. As the renewable or non-conventional energy sources are environmental friendly, economical, have less or no carbon emissions, etc., the power generation from solar/wind are playing important role now-a-days. PV based power generation is becoming popular as the cost involved in it is less while the performance of the system can be improved in both stand-alone and grid connected systems. There are different types of inverters like centralized inverter, string inverter and micro-inverter that are used for the power conversion from DC (available from solar PV) to AC to feed the loads or to connect it to the grid. Since the centralized and string inverters are having problems associated with mismatch under partial shadows, micro-inverters which are connected with each module of the PV system is considered for the effective performance of the system which can extract maximum power from the solar energy. As each module is provided with its own inverter called micro-inverter, the losses associated with the shadowing or shading losses are reduced and hence the utility factor is improved. Hence fly-back micro-inverter is used in applications like stand-alone systems, UPS and utility interactive systems.

In this paper, analysis and design of the Micro-inverter based solar PV system is presented. The basic block diagram of the PV fed micro-inverter system is shown in Figure.1.

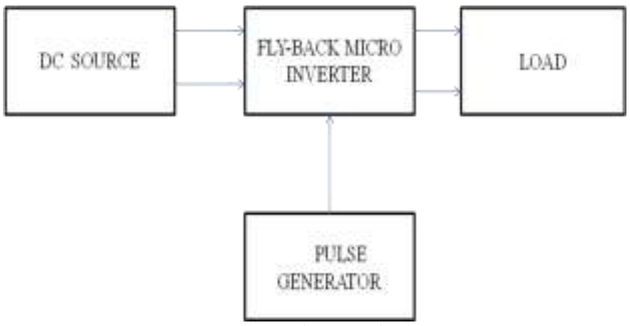

Figure1. The basic block diagram of the PV fed micro-inverter system

A high frequency transformer with a diode rectifier is used to boost the voltage obtained from solar PV to a level based on the turn's ratio. The rectified voltage is then inverted using single phase PWM inverter and is fed to the load Simulation studies are carried out using PSIM software and the results are presented.

Analysis of Fly-back micro-inverter is presented in Section II and design of the inverter system and the filter is discussed in section III. The simulation results are presented in section IV and conclusion is proposed in section V.

II. ANALYSIS OF FLY-BACK MICRO INVERTER

A. *Operation and Design of Fly-back Converter Output*

Fly-back converters are generally used for low power profiles. Here this converter is used to converter DC input to DC output where it performs boost operation. The topology of fly-back converter consists of a switch series with fly-back transformer and diode across the secondary side of the transformer. The basic circuit diagram of a fly-back micro-inverter is given in figure2.

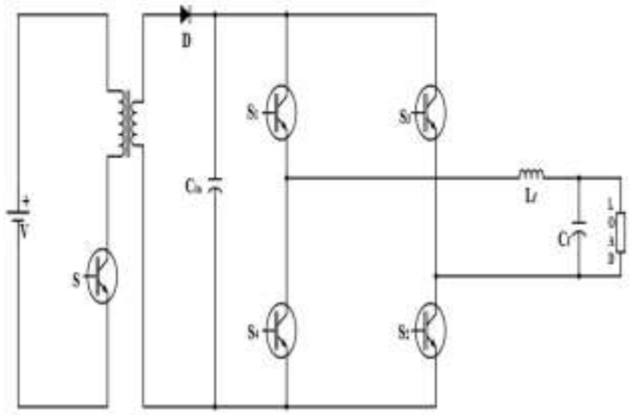

Figure .2 Circuit diagram of a fly-back micro-inverter

1) *During 'ON' state of the switch:*

When the switch gets turned ON, the primary side of the transformer starts storing energy. Due to inverting transformer, negative polarity gets induced in secondary side which results in reverse biasing of the diode (turn off). The circuit diagram during turn on state of the switch is shown in fig.3. The energy obtained from the source is circulated through primary side

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and it gets stored in primary transformer which is acting as the inductor. At this time period capacitor at secondary side acts as voltage source for the load, i.e., the energy stored in the capacitor gets discharged through the load.

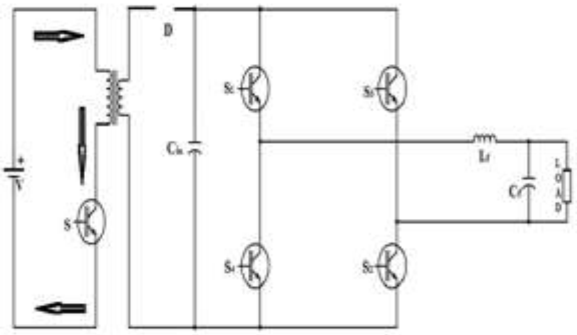

Figure 3. Circuit diagram when switch is turned on

2) During 'OFF' state of the switch:

When the switch is turned off, then diode in the secondary side of the transformer is forward biased and the energy stored in the primary winding is transferred to the secondary. The circuit diagram during the off state of the switch is shown in fig.4. By volt-sec balance method, the output voltage equation can be obtained [1].

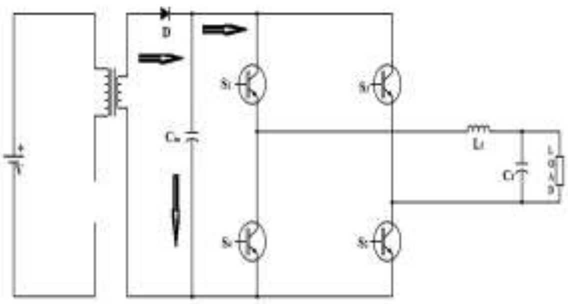

Figure 4. Circuit diagram when switch is turned off

The output voltage to input voltage is given by the equation (1).

$$\frac{V_o}{V_{in}} = \frac{D}{N * (1 - D)} \qquad (1)$$

where, V_o is the output voltage across input capacitor

V_{in} is the input voltage

D is the duty ratio

N is the number of turns across secondary winding

B. Single Phase Inverter

The main objective of this paper is to obtain the sinusoidal output signal. The semi sinusoidal output from the fly back converter is fed as input to the inverter and it converts DC rectified signal to AC signal. The full-bridge circuit is an unfolding circuit for the rectified output voltage of the fly-back that controls the output power direction [2]. The inverter schematic is shown in fig.5. Output of the inverter is 100V and 50Hz. This reduces the switching losses. The output voltage of the inverter is given by equation (2).

$$V_O = \frac{4 * V_C}{\pi} \qquad (2)$$

where,

V_O = Output voltage of inverter

V_C = input capacitor voltage which acts as input to inverter.

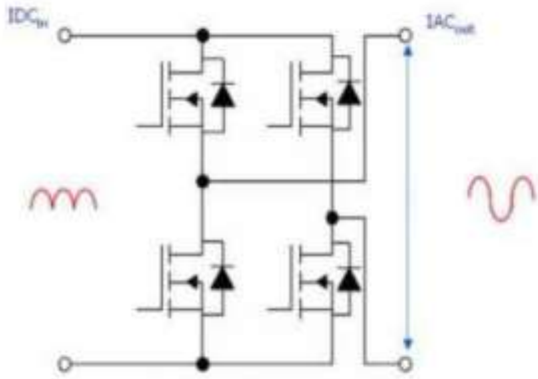

Figure 5. Inverter *operation* schematic *diagram*

III. DESIGN OF FILTER

Filter is connected to the output of the full-bridge unfolding circuit. This filter has been designed with off-the-shelf components that are rated appropriately. Usually at the output of the EMI filter is a 430V varistor across the Line/Neutral terminals, which will add additional protection against transient voltage spikes. After the varistor are two fuses, one in the AC line path and one in the neutral path. The design equations of the filter are stated from equation (3) to (6) and are as follows

$$R_o = \frac{1}{2} * \sqrt{\frac{L}{C}} \qquad (3)$$

$$\omega = \frac{1}{\sqrt{L * C}} \qquad (4)$$

$$\omega = 2 * \pi * f \qquad (5)$$

$$f = \frac{1}{2 * \pi\sqrt{L * C}} \qquad (6)$$

where,

R_O = load resistance

f = inverter bridge frequency

L= filter inductance

C= filter capacitance

IV. SIMULATION CIRCUIT AND RESULTS

Fly-back micro inverter has been designed and simulated using PSIM software. The design parameters are specified in table1.

TABLE I. SIMULATION PARAMETERS

Parameters	**Values**
Switching frequency, f_s	20 kHz
Inductors, Lf	330 mH
Capacitor, C_f	33 µF

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Input Capacitor C_{in}	55 µF
Switch duty cycle, D	0.5
Magnetizing Inductor, L_M	55 µH
Input voltage	25 V
Output voltage	100 V

The simulation circuit of the fly-back inverter system is shown in fig.6. and the simulation results of the output voltage waveforms of the fly-back converter and the inverter is shown in fig.7.

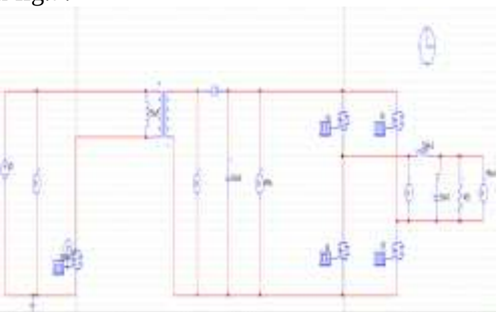

Figure 6. Simulation Circuit of the fly-back inverter

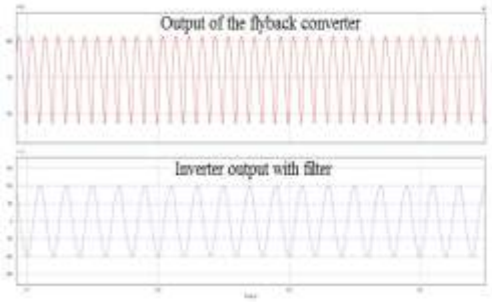

Figure 7. Output voltage waveforms

V. CONCLUSION

Analysis and design of Fly-back micro-inverter has been done and the simulation studies have been carried out on PV fed fly-back micro-inverter system using PSIM software. The system has been designed for a single stage fly-back DC-DC converter with the power output of 215W.The design has been verified using the simulation studies. Further the system can be implemented by developing a hardware prototype to validate the simulation results.

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