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Soft Switched Flyback Microinverter for Photovoltaic Applications with Artificial Intelligence Control

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ABSTRACT— *Renewable sources of energy are becoming more popular due to the environmental concerns and the need for energy. Solar energy is one of the most extensively exploited sources of effective natural energy. The shading effect influences the overall conversion efficiency of the Photovoltaic (PV) system. Microinverters make the solar energy system less prone to effects of shading and thus high system efficiency can be achieved. Microinverters are low power DC-AC converters that are attached to each solar PV panel of a solar energy system which are mainly based on flyback converter topology. The voltage conversion can be done by single step or multi-step topologies. Zero Voltage Switching (ZVS) technique is implemented for this topology with the help of a simple snubber circuit with a few passive elements and variable frequency control technique. An increment in the output voltage and a reduction in the switching losses can be achieved by the implementation of Artificial Neural Networks (ANN) based controller for the closed loop control. High voltage gain is achieved by the modified inverter and thus making the low power inverter for the utilization of PV applications. By the implementation of artificial intelligence based Maximum Power Point Tracking (MPPT) control technique, the Maximum Power Point (MPP) will be extracted within a reduced tracking time. Thus modified system acts as an effective interface between PV system and the AC grid.*

Keywords— Photovoltaic (PV), Flyback Topology, Microinverter, MPPT, Fuzzy, ANN, ZVS.

1, INTRODUCTION

The global electrical energy consumption is ever growing, particularly since the last few decades. This trend is expected to grow further in the future. The reserve of conventional energy sources is not sufficient to satisfy the steady increase in the energy demand. Consumption of these non-renewable energy sources leads to an increase in pollution by the emission of the greenhouse gases. Thus renewable energy gained importance. Among the various renewable resources of energy, the solar energy system based on PV cells is the most popular source. The solar energy is clean, free from pollution, available in abundance and above all it is available to all at fairly equal manner unlike fossil fuels. It has high energy density compared to its counterparts.

India is a tropical country and hence solar PV power system is one of the most promising sources of power in the years to come. However, the investment cost of solar PV system is high. This high cost is mainly due to the components of the system. A PV system generally consists of a PV array, a power conditioner and a battery. Power conditioner mainly includes a DC-DC converter which is followed by an inverter. The necessary isolation should be provided between input and output of the system.

PV modules generate DC which is then converted to AC by a conventional voltage source converter to connect PV modules to the AC utility grid line. The latest technology is Photovoltaic AC Module (PV ACM) also named as microinverter. It is a compact and modular structure for low power PV system applications. In short these are low power inverters in the range 100-350 W. It offers the highest power optimization, design flexibility and also avoids a single point of failure. It is less prone to shading effects.

In this paper, the main focus is given to the MPPT control method and the control of the converter when connected to a grid. The MPPT algorithm employed to the PV module is based on the fuzzy logic. The control of the microinverter is obtained with the help of ANN, one of the artificial intelligence technique.

2, FLYBACK MICROINVERTER

In this paper, flyback topology based microinverter with centre tapped transformer is considered. The flyback type microinverter with regenerative snubber with passive elements is shown (Fig. 1). Compared to the conventional flyback microinverter, it has a snubber with passive electrical components attached to the primary. The snubber circuit consists of a part of transformer winding Tr, a clamp capacitor Cclamp and diodes D1 and D2. Most of the switching losses are turn-off losses as the input to the converter is low. The passive snubber along with ZVS technique implemented in the circuit will reduce the losses and noises. The primary side of the transformer acts like a DC-DC flyback converter with a main power switch. The secondary side of the transformer is composed of two switches (So1 and So2) and two diodes (Do1 and Do2). Since the flyback inverter directly converts the low power DC to AC power, there is no need of a DC-DC boost converter. The flyback transformer not only generates AC power but also provides protect against any electric accident by isolating the PV array from the AC utility grid line.

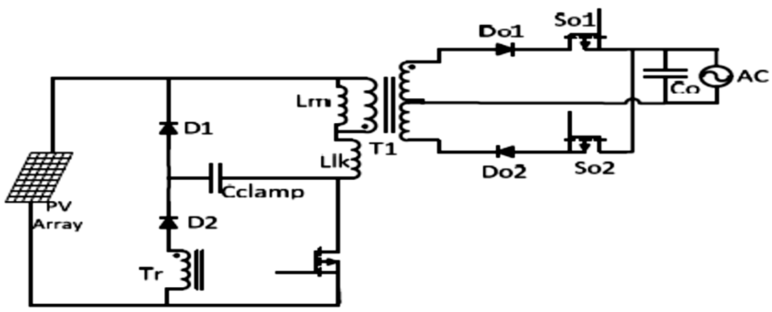


Figure.1 Flyback Microinverter

Before the start of the next switching cycle, the flyback transformer must be fully demagnetized. It is the basic principle that must be considered to ensure that the output waveform of the microinverter is as per requirement. In order to ensure an AC output wave synchronized with grid, the switches on the secondary side are turned on and off in an appropriate alternate manner. For positive polarity of the energy delivered at the AC output

So1 is turned on and So2 is kept off. So1 is off and So2 is turned on, if the polarity required is negative.

3, ANN CONTROL OF CONVERTER

Nowadays ANN has been strongly developed both in theory and in applications. It is a machine learning approach which is a simplified model of biological nervous system. The motivation for such a concept was from the way a human brain performs the computations. By using ANN, artificial intelligence problems can be solved without creating a model of a real dynamic system. ANN involves a highly interconnected network of a large number of small processing elements called neurons. These have the ability to learn and adapt under noise and uncertainty. The connections between the neurons determine the complex global behavior exhibited by them.

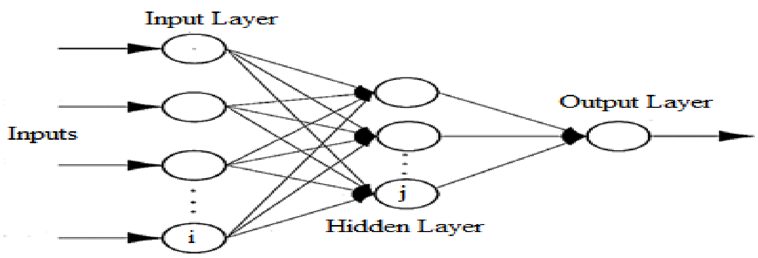


Figure.2 Structure of ANN

Artificial neuron receives a number of inputs and has only one output. In ANN, artificial neurons are organized in layers namely input layer, hidden layer and output layer (Fig. 2.). The network receives the inputs by neurons in the input layer. The input layer communicates to one or more hidden layers which then link to an output layer. The actual processing is done in the hidden layers by a system of weighted connections.

To improve the performance, of the microinverter in the PV cell based system, a multilayer back propagation type ANN controller is used. In this paper, the ANN based controller is used for regulating the gate pulses which are given to the switches at the secondary side of the transformer. The error signal is generated by comparing the actual output voltage of microinverter with the reference grid voltage. The generated error is compensated using the ANN controller. The Levenberg Marquardt Back Propagation algorithm is used to train the network by tuning of the PI or PID controllers, the data set which are used to train the ANN by various algorithm can be obtained. The advantage of this back propagation is that even if it begins far from the final optimum, it succeeds in finding the solution.

4, MAXIMUM POWER POINT TRACKING

Due to rotation of earth and non-linear characteristics between PV panel current and voltage, the PV system has low conversion efficiency. The output current of the PV module is directly proportional to the solar irradiance whereas the temperature and the output voltage are inversely proportional. Thus the output power of the PV system increases with the increase in solar irradiance and decreases with increase in temperature. To obtain the maximum efficiency from a PV system, it must be operated at an equilibrium point. This point of equilibrium is commonly known as Maximum Power Point (MPP). The load connected to the system fed by the PV module decides the operating point to be employed. The operating points of resistive load connected PV system is shown in fig. 3.

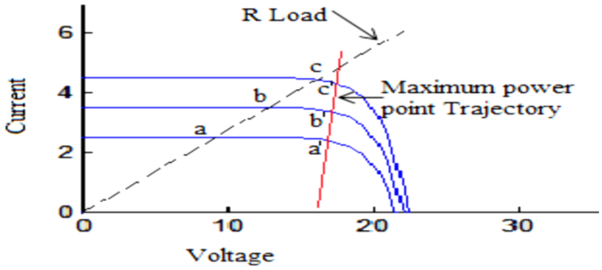


Figure.3 MPPT Tracking of PV Module

For transferring maximum power, the module must be operated at a', b', c' instead of a, b, c. MPPT is employed to regulate the actual operation voltage of the PV panel to the voltage at MPP. This is achieved by changing the duty cycle of the converter connected to the PV system. During years, many MPPT techniques have been developed and implemented such as Perturb and Observe (P&O), Incremental Conductance, constant voltage method, fuzzy logic etc. The choice of MPPT method mainly depends on its complexity and the time taken to track the MPP. The characteristics of power and current of PV cells become more complex under non - uniform and partial shading conditions. This increases the difficulty in tracking the MPPT. All environmental conditions must be considered to design a MPPT technique in order to get satisfactory results. Artificial intelligence based designs are capable of producing appropriate solutions under these conditions. In this paper fuzzy logic based MPPT method is taken into consideration.

4.1 Fuzzy Logic based MPPT:

The fuzzy logic based MPPT algorithm aims to track MPP accurately and at a fast rate. The variations in atmospheric conditions and non-linearties result in uncertainties in the PV system. The Fuzzy Logic Controller (FLC), a robust controller has high capabilities to handle these states of uncertainty. Figure 4 depicts the components of FLC. Duty cycle of the converter is varied till the error calculated becomes zero (dP/dV = 0). Only two signals from the PV module are required to design the system, thus making it simple and easy to implement. The required signals are Error signal (E) and Change in Error signal (CE). The equations (1) and (2) can be used to calculate the error and change in error.

$$\mathrm{E(n)} = \frac{\mathrm{P(n)-P(n-1)}}{\mathrm{V(n)-V(n-1)}} \qquad (1)$$

$$CE(n) = E(n) - E(n-1) \qquad (2)$$

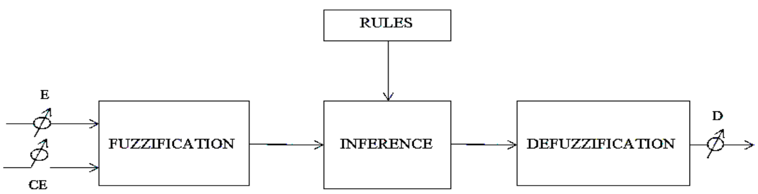


Figure.4 Block Diagram of Fuzzy Logic Controller

The output of the FLC is considered to generate the gating pulses to the main power switch as shown in fig. 5.

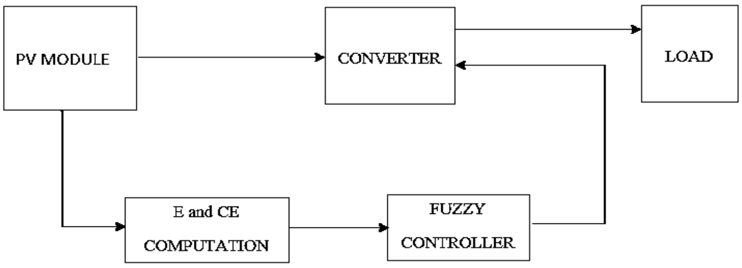
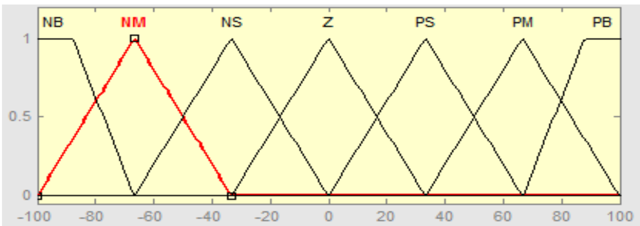
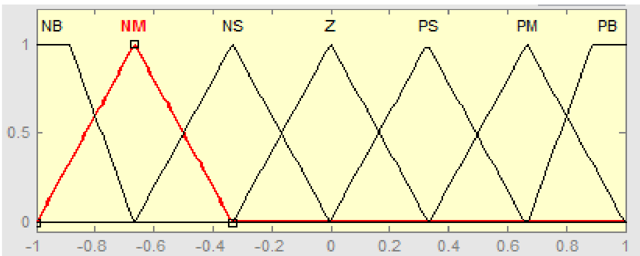


Figure.5 Fuzzy Logic MPPT Method

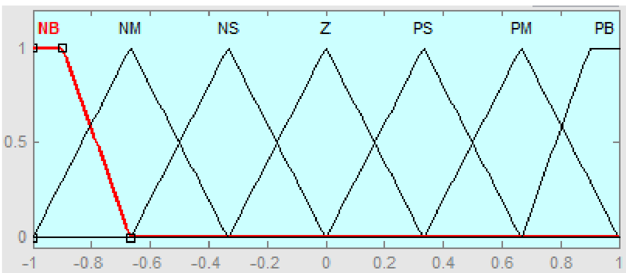
The designed membership functions for inputs (E and CE) and the output is shown in fig. 6.



(a) The Membership Function of the Error Signal



(b) The Membership Function of the Change in Error Signal



(c) The Membership Function of the Output of FLC

Figure.6 Different Membership Functions of the Fuzzy Logic System

The rules implemented between the input variables are listed in table I.

Table I. The Rules of the Fuzzy Logic System

CE / E	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NM	NM	NS	ZO	PS
NS	NB	NM	NS	NS	ZO	PS	PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PS	PM	PB
PM	NS	ZO	PS	PM	PM	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

5, SIMULATION RESULTS

The proposed system was simulated in MATLAB/Simulink software. The converter was implemented with input voltage in the range 40-50V and the grid reference voltage was considered to be 110V. The main power switch is operated at high frequency of 60 kHz. The input to the converter is fed from a simulation model of PV system. MPPT technique employing fuzzy logic is implemented for efficient utilization of the PV array. ANN based control method is implemented for improving the performance of the microinverter. The THD of the output voltage is less than 5% which is within the standard limits. The simulation model of the proposed system, the output voltage waveform and the THD of the system is shown (Fig. 7, Fig. 8 and Fig. 9 respectively).

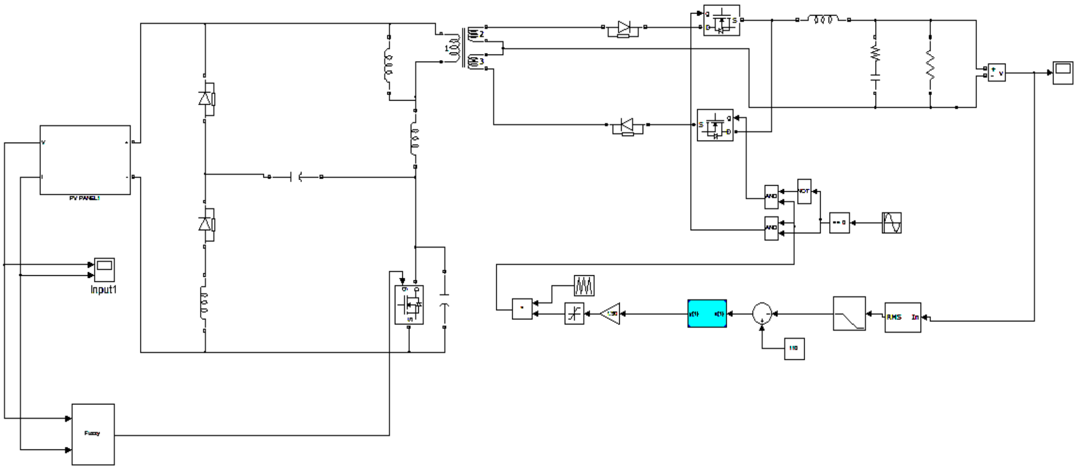


Figure.7 Simulation Model of the Proposed System

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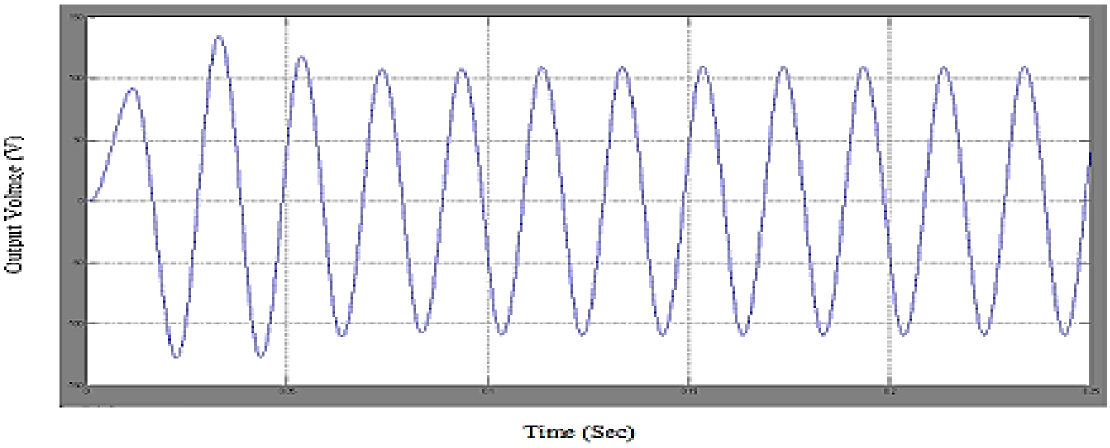

Figure.8 Output Voltage Waveform of the proposed system

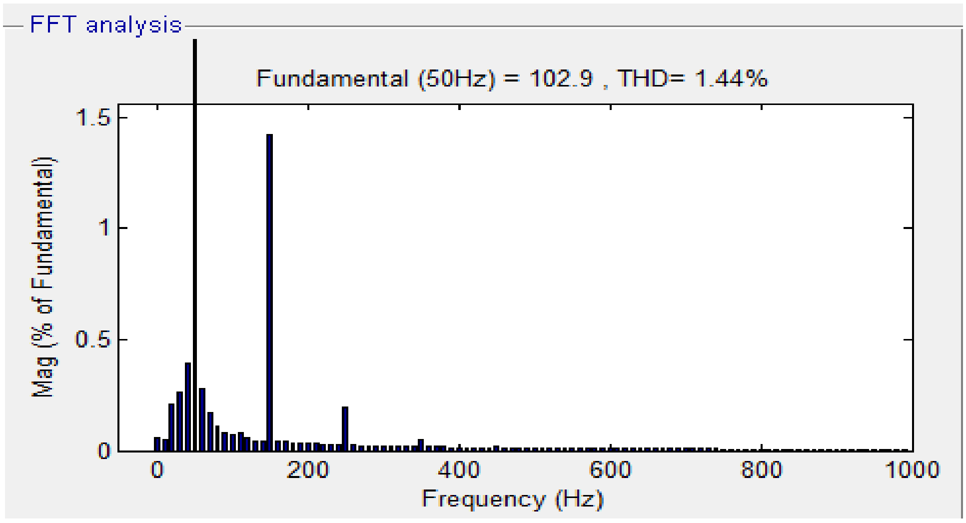

Figure.9 THD of the Proposed System

6, CONCULSION

A PV system with fuzzy logic based MPPT fed flyback microinverter with ANN controller is proposed. The flyback microinverter considered has only one switch being operated at high frequency which results in low switching losses. Soft switching is implemented which further reduces the losses especially turn-off losses. The flyback high frequency not only boosts the voltage obtained from the PV panel but also provides isolation.

The output of the PV panel varies mainly with changes in solar irradiance and temperature. This uncertainty is dealt efficiently by the fuzzy logic MPPT technique. The artificial intelligence based MPPT is discussed in detail. The fuzzy logic MPPT is fast and accurate in MPP approximation. The ANN controller implemented in the system improves the performance of the converter. The control of the gate pulses given to the secondary switches of the converter through ANN logic is discussed. The THD is reduced to below 5%.

Volume: 2 Issue: 2 Jun,2016,ISSN_NO: 2321-4775

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