# Modelling and Dynamis of an Fpga based Pwm Solar Power Inverter :An Effective Solution for Power Crisis in Rural India

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## ABSTRACT
The paper presents development of a utility interface solar power converter (Inverter) in Grid / DG power supply for a Solar lighting system used in rural home of Indian villages. The power supply system comprises of solar (PV) array, PWM converter incorporating PWM control strategy,energy storage battery devices. The model of the system has been designed for its operation and a prototype solar power converter. The system simulation of PWM Pulse generation has been done on a XILINX based FPGA Spartan 3E board using VHDL code. The test on simulation of PWM generation program after synthesis and compilation were recorded and verified on a prototype sample.

## Keywords
Solar inverter, PWM, FPGA control, PV etc

## 1. INTRODUCTION
The basic need of an electrical energy is increasing with the rapid growth of population in urban, suburban and rural sectors. On the other end, the conventional grid supply in a grid connected area has become standstill due to diminishing trend of raw material resources and its further extension is not possible due to various technical, political and economic reasons. To meet the excess energy demand, alternative renewable energy sources like solar/wind etc with energy storage device i.e. Battery are being used to work as a standalone power source or in sharing mode with Grid or DG power source. Among these two sources solar energy is preferred as it is easily available in every part of the country in the world where as wind energy is restricted to the coastal area only.In the present study, a solar (PV) power system has been proposed with simple technology which can work as a standalone device or as a primary source of hybrid power supply system i.e. integrating PV system with Grid / DG set.

## 1.1 SYSTEM MODEL DESCRIPTION
The solar home light model consists of the following units as shown in Fig. 1.

· Solar PV module

· Intelligent control unit

· PWM Inverter

. Battery charger

### 1.1.1 *Solar Photovoltaic module*
A solar photovoltaic module is the basic element of each photovoltaic system. It converts solar energy into DC electricity when sunlight falls on its surface. This DC signal is converted to AC by inverter to meet AC load requirement of houses. The future will see everyday objects such as, the rooftops of cars and even roads turned into power-generating solar collectors.

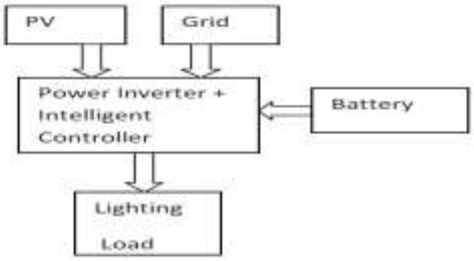


**Fig. 1.Block diagram of proposed solar lighting scheme**

**Fig. 2. solar photovoltaic module**

### 1.1.2 *Solar inverter cum charge controller with intelligent logic control*
Solar Inverter converts DC power from battery, charged from PV source, to AC power compatible with the utility and AC loads. This unit consists of solar inverter cum charge controller with intelligent logic which controls the charging of battery from solar or mains or both with solar as priority in sharing mode. This system monitors the battery charging status and accordingly decides to charge the battery either from solar or from mains or both in sharing mode. First priority of charging is from solar modules and only in the absence of solar power (no-sunshine time) and when battery voltage is low (a predetermined level), the mains charger is turned ON automatically. This maintains the battery on float.


**Fig.3. Connected appliances**

### *1.1.3 Battery charger*

A device that converts the chemical energy contains in its active material directly into electrical energy by means of an electrochemical reaction. Low maintenance tubular type batteries are provided with the system. Battery deep discharge,over charge protections are incorporated inside the solar converter.The battery charge is controlled through constant charging regulator module using PWM technology. Design incorporate auxiliary source i.e. grid which charges the battery in sharing mode with solar (PV) as first priority to charge battery attaining full voltage.

## 2. INVERTER TOPOLOGY

Inverter is a device which converts the DC power source into AC power a centre-tap inverter topology has been configured to generate PWM sine wave pulses as shown in Fig.2. The semiconductor Power switches may be controlled to produce a

multilevel three output voltage state:

V0= +V dc (T1 Closed)............................ (1)
V0= - V dc (T2 Closed)............................ (2)
V0= 0 (Transition from Vcc to – Vcc).... (3)

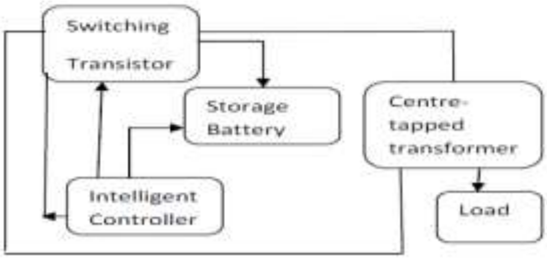


**Fig. 4. Circuit diagram of power inverter**

## 3. SYSTEM CONFIGURATION

The block schematic diagram of FPGA based PWM solar inverter is shown in below figure. 5. The system works under three modes of operation namely:Charging Mode (PV/Grid during sunhour/available Period )Mode (Grid Cut off or restricted (load shedding Period )Optimally controlled DG operation (during the period when the system does not support to deliver power to load)In the charging mode, the input energy obtained through PV source during sun- hour is stored in battery to a level more than 12V till it reaches cut-off limit of 13.4V. The charging is also shared proportionately with the grid/DG source using time regulator circuit through sinusoidal PWM bi-directional inverter, if needed during the low radiation/cloudy period, to meet the required end user load energy demand.

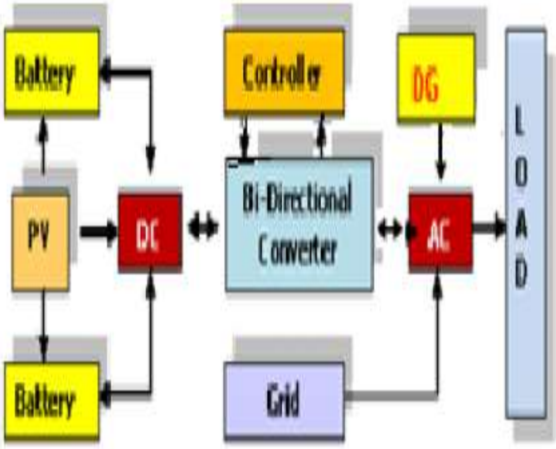


**Fig. 5.Block Diagram of Solar PWM Inverter Power supply system**

The main switching signal (MSS) and polarity control signals (PCS) for N number of PWM base drive pulses is generated by software program. The PWM control base drive gate signals switch on and off the positive group and negative group of inverter power switching devices and thus produces PWM AC pulses approximated to sine wave as shown in Fig.6.

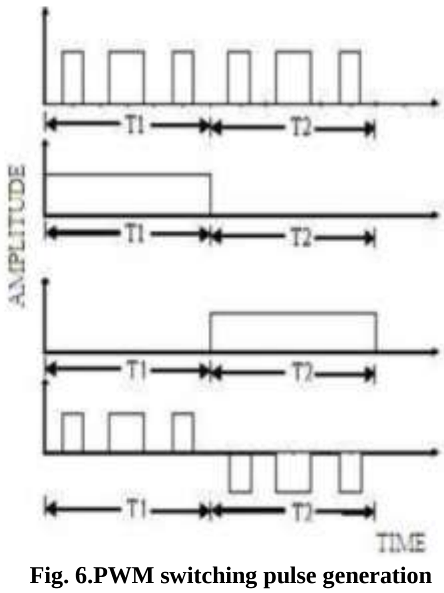


**Fig. 6.PWM switching pulse generation**

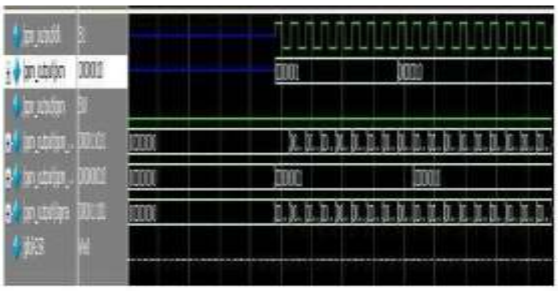

**Fig.7. PWM results**

Software programme of PWM generation was downloaded in FPGA Sparton 3E board using Verilog HDL code. The result of simulated wave using in Fig.7.

The hardware implementation has been done through FPGA Spartan 3E board in Fig.8.FPGA controller with Power converter produces PWM waveform at its output.

The waveform of PWM control pulses and the approximated sine-wave produced inverter across load is recorded in oscilloscope as shown in below figure 9
The PWM pulses as shown in fig.6. are generated by the software using following mathematical expression

$P_i = K\ (180/N) * [2 \sin (2i-1)\ \pi/2N]$......(4)
Where i = 1 …N (number of PWM pulses)
Pi = Pulse width of PWM pulses
K= (Voltage Regulating Factor (0-1)

# 4. EXPERIMENTAL INVESTIGATION

The software used to design the system is XILINX 9.2i. It is a vast software mainly used in industries for designing, testing and development of digital ASIC's. The software process of the system is basically divided into three stages:

- Design
- Implementation
- Simulation

During the design stage shown in results and discussion, the VHDL code for the generation of SPWM waveform from the FPGA has been written.

# 5. RESULTS AND DISCUSSION

## 5.1 Software Simulation of Intelligent Controller

The hardware implementation has been done through FPGA Spartan 3E board in Fig.8.FPGA controller with Power converter produces PWM waveform at its output..

**Fig. 8. FPGA Sparton 3E board**

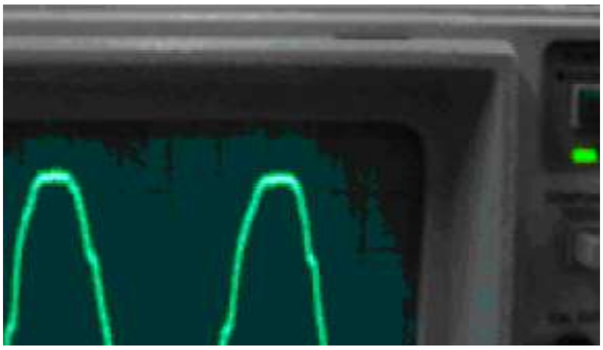

**Fig.9. Oscilloscopic image of MSS**

## 5.2 Analysis and Simulation Result of Prototype Power Inverter

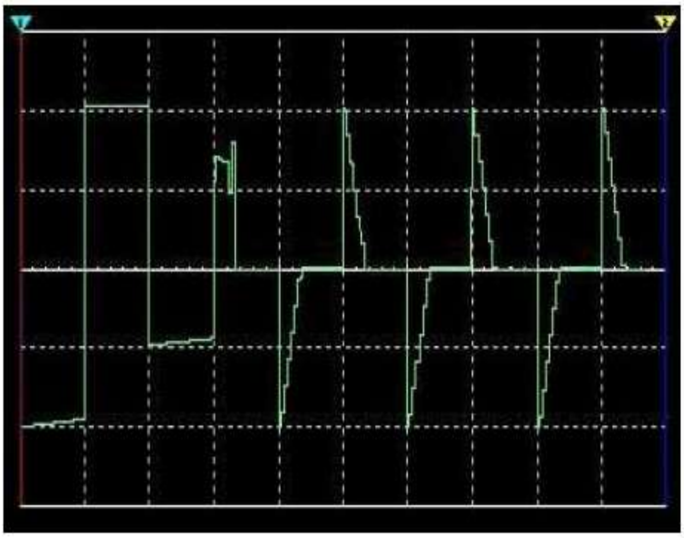

**Fig.10. starting simulation of power inverter**

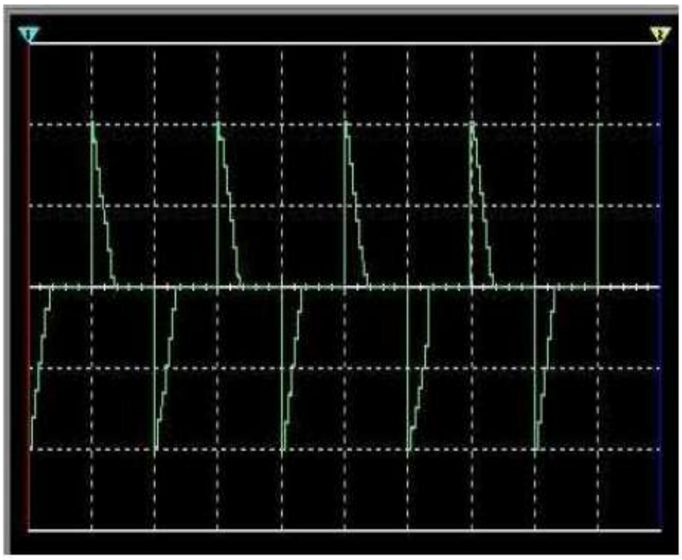

**Fig. 11.continuous simulation of power inverter**

The optimization of the inverter design was to improve the high power efficiency of the inverter.This optimization and development process was based solely on 12 volt DC inverter since the low voltage inverters always have a lower efficiency due to the very high DC current that has to be processed. To further optimize the inverter, higher DC voltage versions of the inverter design would need to be built and tested to determine the best ways to improve efficiency overall. Due to the limited development time, the higher DC input voltage versions were given a lower priority and the 12 volt DC version was the focus of this research and development. The inverter produces AC power output with DC. power input .The efficiency of Inverter depends on harmonic content in ac output power which depends on the number of PWM switching pulses i.e. N approximated to a sine wave in both the half cycle of output AC wave

**Fig.12. hardware simulation in oscilloscope of power inverter using PWM pulses continuous**

## 6. CONCLUSION

The performance of the proposed system is better and its software controlled features offer more flexibility as compared to other PV converter system. The use of FPGA technology to generate PWM pulses for solar inverter using Verilog HDL programming language has successfully beenimplemented in the present study. The software controlled programme can alter the inverter parameter(s) and can easily be outputted through FPGA board. The grid interactive PV inverter can also be used as a stand-alone Power supply by adding more number of PV module as per load requirement in a grid deprived area.

## 7. SUMMARY

In this, investigations have been carried out on the development of solar power Inverter as an alternative or supplementary source to conventional grid for home applications. The following features have been included in the system. The technology used in the proposed scheme is simple, cost effective and having fast response in terms of control stability under varying solar radiation. The system can be scaled to higher rating easily. It is easily maintainable and confirm to sinusoidal quality with low switching loss. The load power adaptability feature of inverter and PWM control strategy offer almost constant efficiency.

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