MANTECH Publications

Journal of Research in Electrical Circuits and Systems
Volume 4, Issue 3, September-December 2019

A Novel Approach to Dual Boost Converter for Grid Linked PV Inverter

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Abstract

In this paper a novel approach for dual boost converter is presented which is applicable to transformer less grid linked inverter. The input voltage from solar modules given to boost converter should be fixed. But due to environmental causes it varies. For a certain range of variations in input it is controlled by controlling the PWM triggering of MOSFET in boost converter circuit so that the output of the boost converter is a fixed output. This approach is analyzed, designed and simulated using MATLAB/SIMULINK, curve fitting in MATLAB and generating formula, implementing the formula using VHDL on Spartan 3 FPGA and also on AVR microcontroller.

Keywords: *Dual Boost Converter, Duty Cycle, Pulse triggering*

INTRODUCTION

Renewable energy sources in present situation are in a great demand in particular in area of PV (Photovoltaic energy system) of all available worlds' energy. This system is freely gifted by nature, available in enormous amount. It is a renewable source which is pollution free, environmental friendly and it is the source which is going to be popular of all other energy sources in near future.

With advancement in technology in present time this system is going to get utmost importance because of decrease in cost of PV modules day by day and in coming years it will be the one of the utmost source of energy. The reduction in PV modules cost have a direct impact on reduction of price of grid linked transformer less inverter and hence system will be more effective and known from cost point of view. [3, 4].

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The most common application of PV system is that they are used as power plant and in grid linked inverter as power sources. They are also used to provide power to the social communities all over the world. Also to reduce dependence on fossil fuel and to encourage low carbon emissions our government machinery is encouraging us to install, more and smaller grid linked inverters for meeting the demand of power. Although such inverters are about 25% cost of PV organization [1]. In this area continuous hard work is in progress so as to lessen the cost of the system and its trustworthiness.

PV solar panels and inverters may be used in different configurations, and the commonest solution is to associate singlephase or three-phase central inverters with PV panel strings [2].Mostly for boosting the input voltage we use transformer else the input voltage more than grid voltage. This method is not good in PV operation due to characteristics of PV panels /modules differ with time. In PV grid linked transformer less inverter designing of an ideal DC to DC converter is a great challenge. This converter is used to boost the PV input voltage. It will convert the low and varying voltage from the PV array to a constant DC voltage.

In this paper the boost converter designed converts the varying input of around 24 Volts into a fixed 312 volt output in two stages. In the first stage 24V DC converted into 86V DC and in second stage it is converted to 312V DC. [8, 9] This is done in the circuit by the help of controlling PWM pulse triggered to MOSFET of converter and hence by varying pulses duty cycle to the switches, we can control the output. So that the output is constant for varying input voltages.[5]

The switches in the circuit implemented for boost converter is also a great challenge. In converter we can use either MOSFET/IGBT as switches. Generally for voltage (V>1000V) and low frequency (f<20 KHz) IGBT s are used. For low voltage (V 200 KHz) MOSFET s are used. In this paper in the boost converter circuit we have used MOSFET s as a switch.

In the dual stage converter circuit [6] designed in MATALAB/SIMULINK environment, PWM controlling technique analysis is done for the circuit. As the input from PV modules varies and it depends on environmental factors. Thus PWM control technique is used by varying the duty cycle of the MOSFETs used in the circuit so as to get a constant output. The output of variations are tabulated and curve fitting in Mata lab has been used for generating the formula and the formula is implemented in VHDL on SPARTAN 3 FPGA and on AVR microcontroller for real time hardware solutions.

D.C TO D.C CONVERTER

This converter input is a DC and output is also a DC voltage but at some other voltage than input. Thus device is utilized as conversion of voltage level, noise isolation and power

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regulation. The major application of converter is it changes unregulated Dc voltage into regulated /varying Dc voltage. This is controlled by a switching concept and PWM modulation technique.

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage which is typically at a different voltage level than the input. Apart from voltage level conversion, DC-to-DC converters are used to provide noise isolation, power bus regulation. The output voltage in DC-DC converters is generally controlled using a switching concept. In fact, early DC-DC converters were known as choppers with silicon-controlled rectifiers (SCRs) used as the switching mechanism. Modern DC-DC converters employ insulated gate bipolar transistors (IGBTs) and metal oxide silicon field effect transistors (MOSFETs) as they possess attractive switching capabilities, especially in terms of switching frequency and power ratings. Based on their performances, DCDC converters are subcategorized into three general types; Buck Converters which convert from a voltage level to a relatively lower voltage level. Conversely, Boost Converters transform to higher voltage level. The third one is buck-boost converter which can either be a buck or a boost converter based on its control signals.

A DC–DC converter with a high step-up voltage gain is used for many applications, such as high-intensity discharge lamp ballasts for automobile headlamps, fuel-cell energy conversion systems, solar-cell energy conversion systems, and battery backup systems for uninterruptible power supplies. Theoretically, a dc–dc boost converter can achieve a high step up voltage gain with an extremely high duty ratio. However, in practice, the step-up voltage gain is limited due to the effect of power switches, rectifier diodes, and the equivalent series resistance (ESR) of inductors and capacitors. Moreover, the extremely high duty-ratio operation will result in a serious reverse-recovery problem. Many topologies have been presented to provide a high stepup voltage gain without an extremely high duty ratio. [7]

Dual stage power converter is used to step D.C voltage. This boost voltage is made up by input energy storage in magnetic/electric components of the circuit and by transferring the energy to output at some other voltage. [5]

D.C TO D.C CONVERTER CONTROL STRATEGY

A boost converter is a circuit in which transfer of energy from input end to output end requires a power switch, an inductor, and a diode .The function of inductor is to control the current slew rate along the power switch. Thus it controls the high-peak current or else it would be controlled by the switch resistance alone.

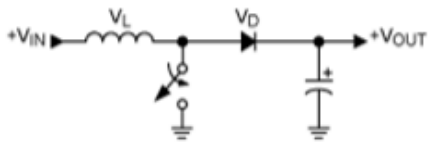
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The benefit of using an inductor in boost circuit is that an inductor stores energy. This energy is given by, $E = ½ \times L \times I^2$

Where E is in Joules and it is a function of the current.

Moreover a linear circuit has a power drop in the form of voltage drop which results in heat. In the converter type of circuit it has no voltage drop and moreover current is 90 degrees out of phase with the voltage and hence energy is first stored and then it is get back during release phase of the overall switching time period. Thus overall efficiency is improved and it has less dissipation losses.

A simple Boost convert circuit is shown Below



During charging phase when switch is closed the inductor current rises linearly with respect to time. Thus it is proportional to input voltage divided by the inductance.

And during discharge phase when the switch is open the inductor current continues to flow through the diode so as to charge the output. As the output voltage rises, the slope of the current, di/dt, though the inductor reverses. The output voltage rises till equilibrium condition hence:

$V_L = L \times di/dt$

Thus, more the inductor voltage, the faster the inductor current drops .Under steady state the entire average voltage appearing along inductor during switching period is zero. This implies that average current through inductor is in steady condition. This is a very important point in all switching inductor based topologies. Thus under steady state, charge time tON, for a given input voltage and discharge time tOFF, for a given output voltage, the mean inductor voltage in steady state condition is zero, thus for the boost circuit:

$V_{IN} \times t_{ON} = t_{OFF} \times V_L$

But,

$V_{OUT} = V_{IN} + V_L$

Thus the above relation, we have

$V_{OUT} = V_{IN} \times (1 + t_{ON}/t_{OFF})$

And in above relation duty cycle

(D): $t_{ON}/(t_{ON} + t_{OFF}) = D$

Thus for the boost circuit:

$V_{OUT} = V_{IN}/(1-D)$

Thus by changing the duty cycle we can control the steady-state output with respect to the input voltage. This is the main

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criteria used in the boost converter circuit.[9,10,11]

The Boost converter circuit designed in MATALAB/SIMULINK environment is as shown in fig.1 [6]-

The Boost converter circuit designed [6] is taken and control technique was used in the circuit of boost converter designed and in the power converter circuit MOSFET s used are controlled by PWM and by varying the duty cycle of two stage converters and the output is controlled.

In the above circuit values of components taken are –

Vs=24 V DC

L1=190e-3 H

L2= 20e-3 H

C1 = 3.5e-6 F

C2 = 1e-6 F

R_1 = 133.1ohm

R_L = 59.1 ohm

The parameter values are taken with reference to the paper [6].

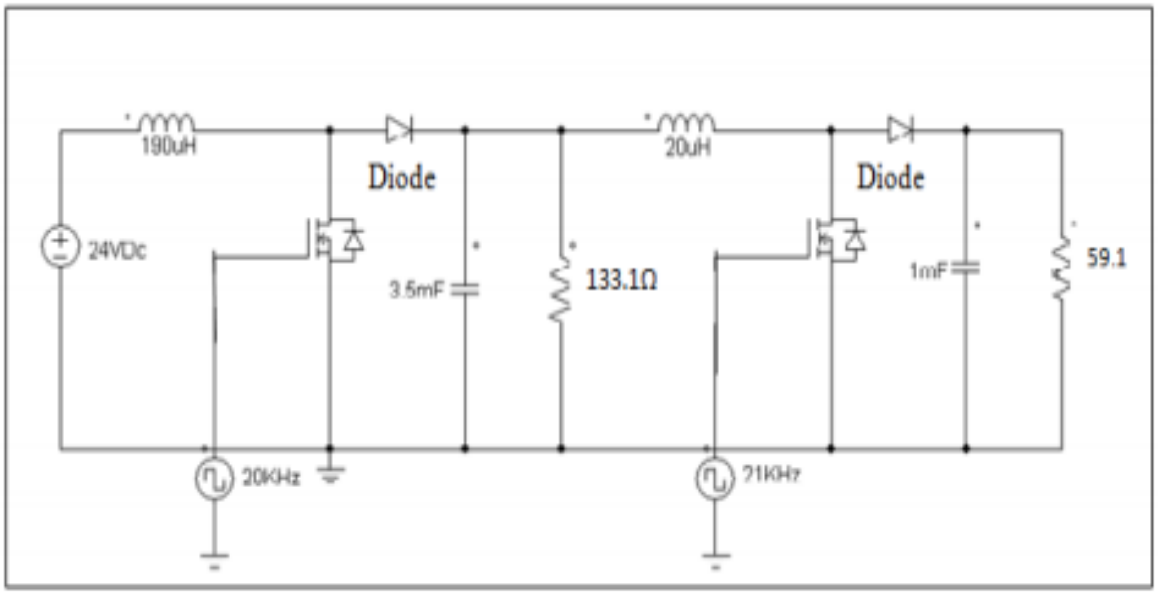


Fig. 1 Dual stage Boost Power Converter Circuit

SIMULATION RESULTS AND DISCUSSION

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Simulation circuits of Boost ConvertersFirst Stage Boost Converter Model

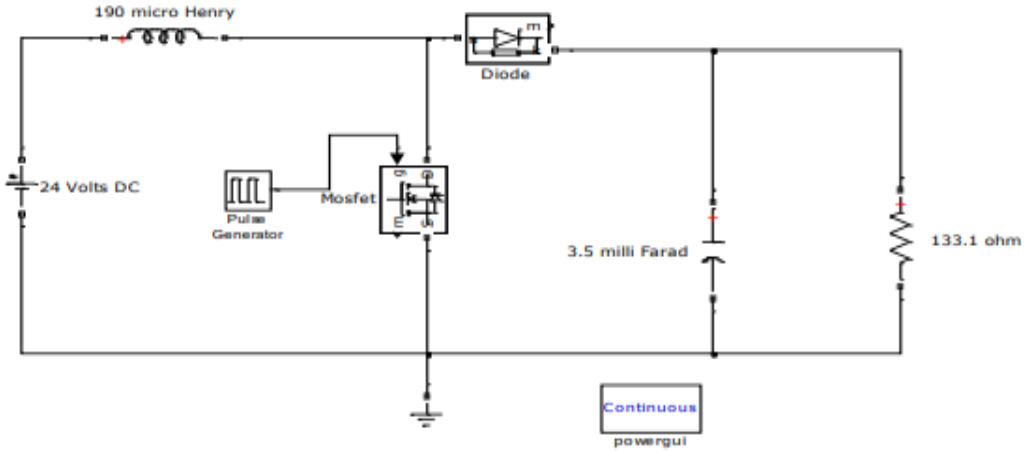


Fig 2 (a) First stage boost converter circuit model

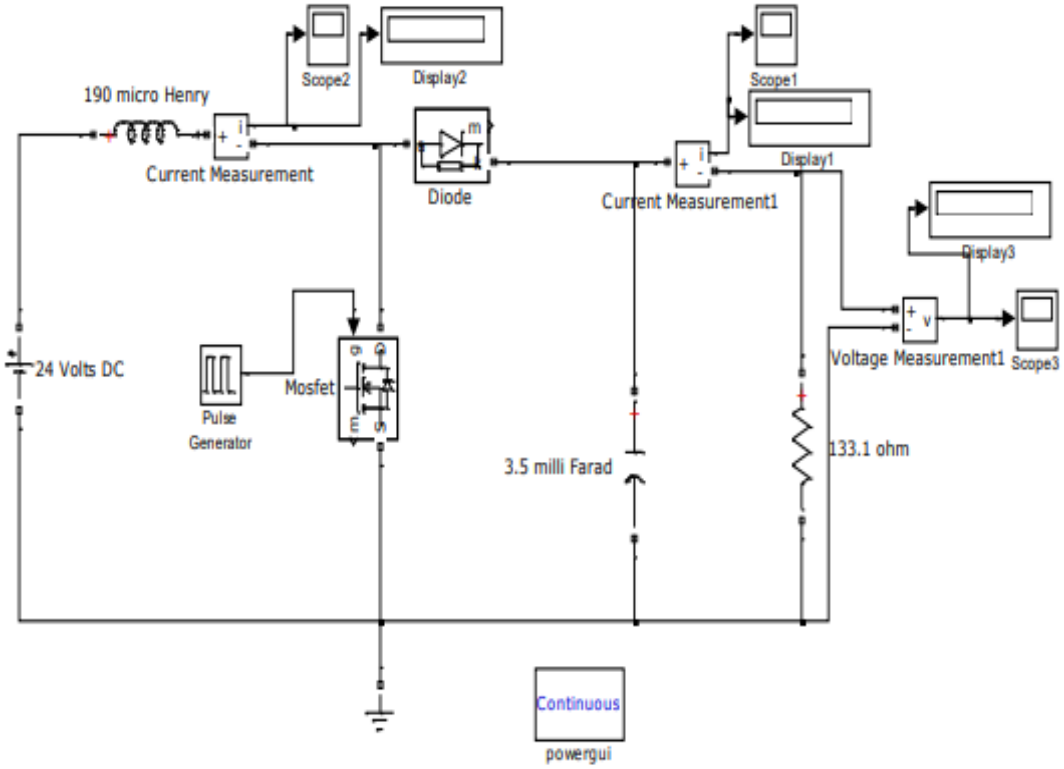


Fig 2(b) First stage boost converter simulation circuit

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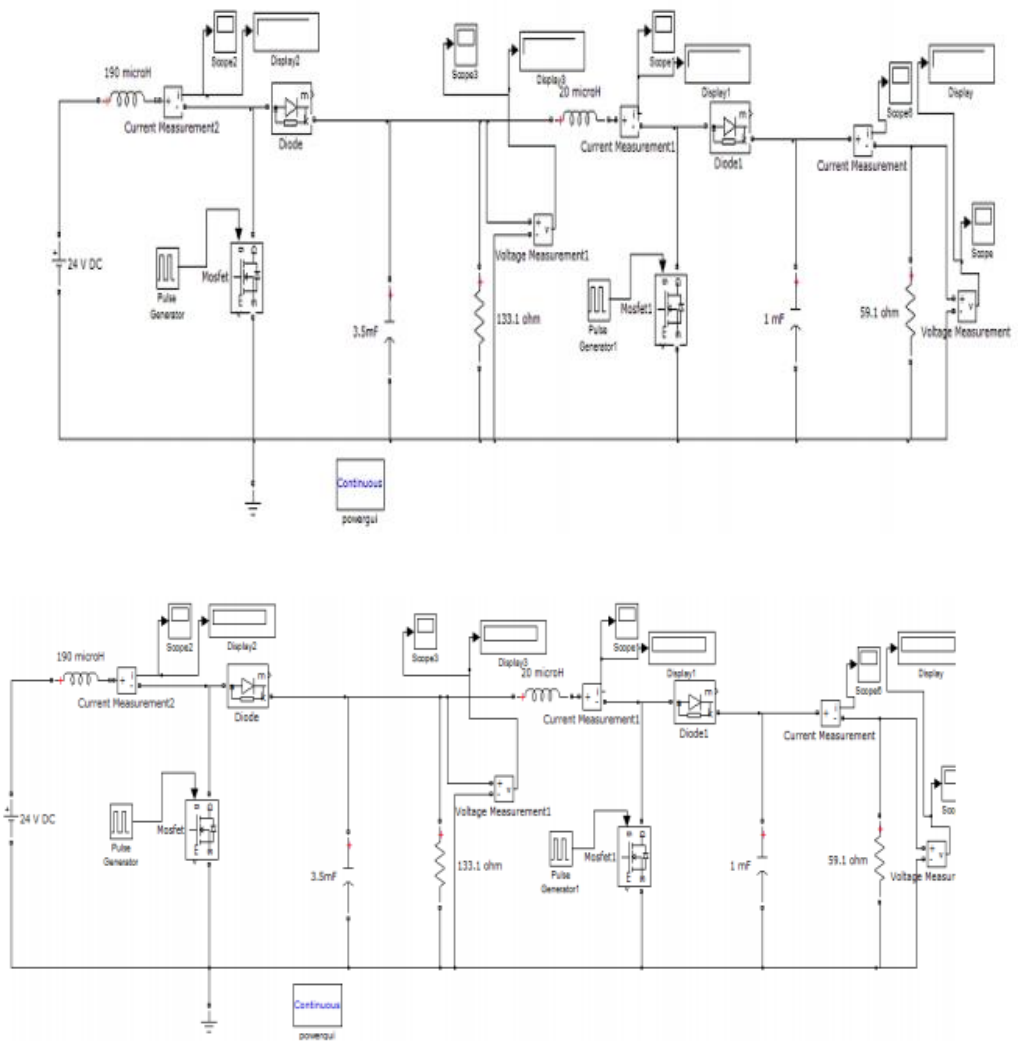


Figure 3 Dual stages Boost Converter Model

In fig 2(a), 2(b) and in fig 3 Simulation of Boost Converter circuit is done using Mat lab / Simulink for PV applications circuit. In fig 2 Single stage Boost Converter circuit is simulated and in fig 3 Dual stages Boost Converter circuit is simulated. In the above circuit we have taken DC voltage source as input, MOSFET s as switches. Two inductors, two capacitors & load resistances in both first and second stages. The measurements in the circuit are done using scope and signal generator is used for triggering MOSFET s and power GUI is also used for analysis. By varying the input voltage for a certain range and changing pulse triggering in a way to get constant Output voltage of 312 V, the circuit was simulated and the output obtained is as in table 1.In the table D1 and D2 are duty cycle for first and second stage MOSFET s respectively.

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Table 1

V_i	D_1	T_1	T_2	D_2	V_o
24	72%	5.00E-05	3.23E-05	83%	312
23.97	72%	5.00E-05	3.25E-05	83%	312
23.96	72%	5.00E-05	3.26E-05	83%	312
23.95	72.15%	5.00E-05	3.29E-05	83%	312
23.925	72.18%	5.00E-05	3.33E-05	83%	312
23.9	72.22%	5.00E-05	3.37E-05	83%	312
23.87	72.24%	5.00E-05	3.43E-05	83%	312
23.86	72.26%	5.00E-05	3.44E-05	83%	312
23.85	72.26%	5.00E-05	3.47E-05	83%	312
23.825	72.30%	5.00E-05	3.53E-05	83%	312
23.8	72.33%	5.00E-05	3.61E-05	83%	312
23.77	72.36%	5.00E-05	3.67E-05	83%	312
23.75	72.38%	5.00E-05	3.77E-05	83%	312
23.725	72.41%	5.00E-05	3.87E-05	83%	312
23.7	72.44 %	5.00E-05	4.00E-05	83%	312
23.68	72.47%	5.00E-05	4.28E-05	83%	312
23.67	72.48%	5.00E-05	4.30E-05	83.20%	312

From above results it was found that for input variation from 24 V to 23.67 V the output obtained is a constant output which is our objective. Using the above results using curve fitting in Mata lab/Simulink generated a formula for the above results. For this an M file was created in MATALAB/SIMULINK. The output of M file is a graph between input voltage and second stage MOSFET triggering time as shown below in fig (4)

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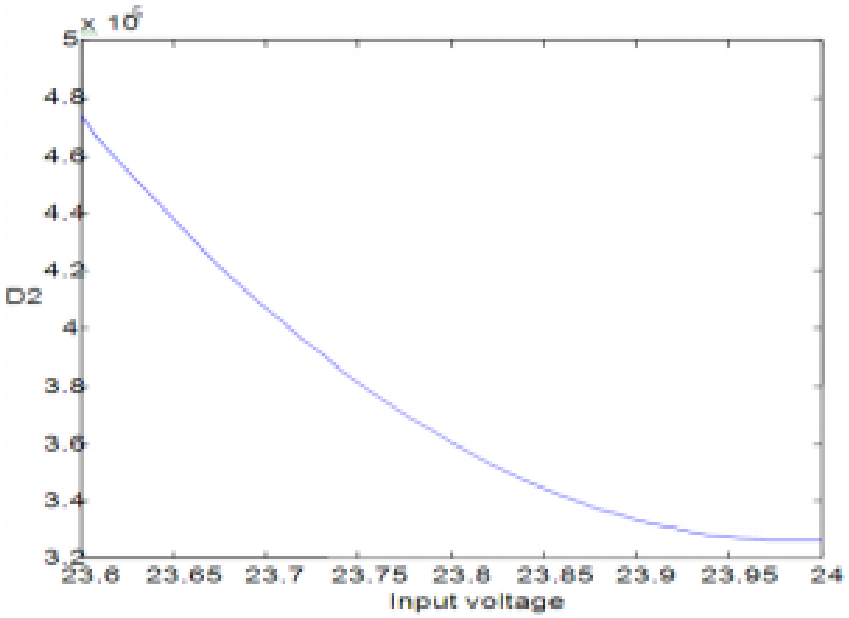


Fig (4)

The M file is used to calculate formula and graph between the variables.

From M file a generalized formula is obtained for calculating the values of time period for second MOSFET triggering pulse due to change in input voltages. The generalized formula obtained is as follows

cf = Linear model Poly2:

cf(x) = p1*x^2 + p2*x + p3

Coefficients (with 95% confidence bounds):

p1 = 9.941e-05 (7.318e-05, 0.0001257)

p2 = -0.004769 (-0.006019, -0.003518)

p3 = 0.05722 (0.04232, 0.07212)

In the above formula x is the input voltage and p1, p2, p3 are Coefficients.

For an input voltage we can calculate the value of T2 and simulation can be run to get desired output voltages. The above formula is valid for variations in input in the range of 24 to 23.6 volts. Using the above formula the range can be further extended.

RTL IMPLEMENTATION FOR THE FORMULA

VLSI Front End Implementation opens the path for hardware implementation of the proposed work. With the approach the formula is implemented on VHDL language using Xilinx ISE 14.1 Software. Simulation results for the implemented design are shown on Modelsim Software. For the output pulse width to be converted

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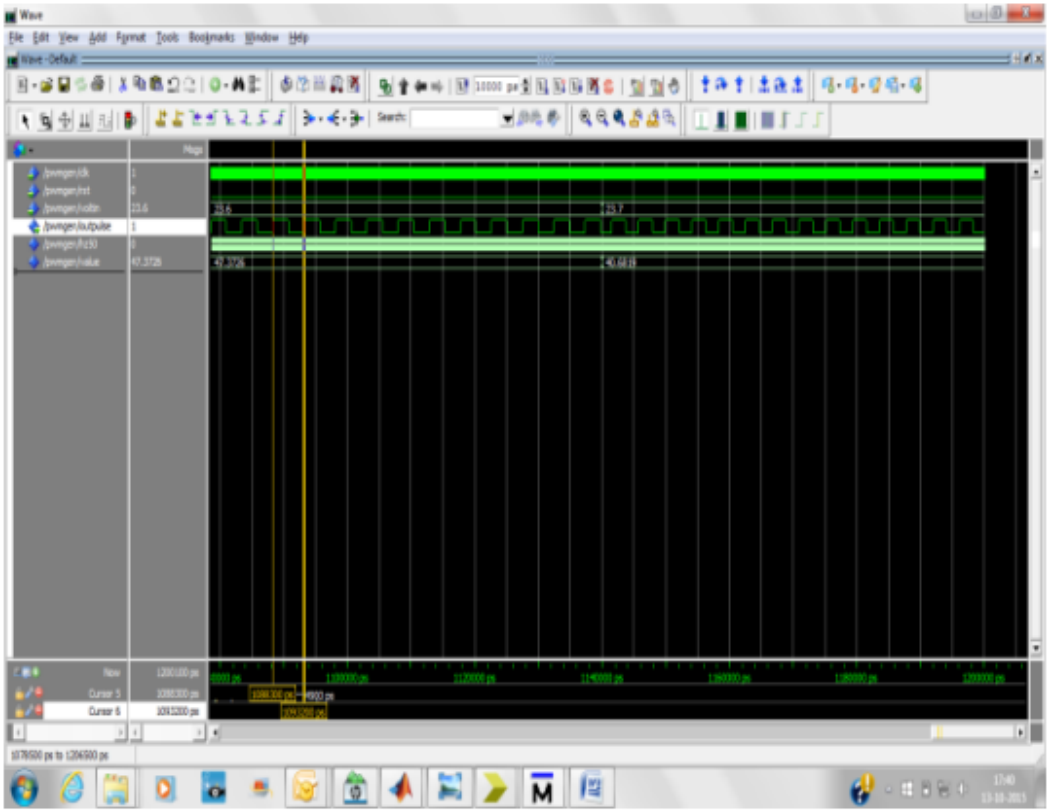
the logic is implemented in the VHDL code is as given.

The curve fitted formula results in the desired pulse width. With the given source clock on the FPGA the following logic can be used to generate the final pulse width signal.

Example given source clock 100ps i.e. 10GHz. Output of the curve fit formula is 43.0 microseconds pulse with 50% duty cycle. So we will convert the 43.0microseconds into picoseconds i.e. 43000000 ps. For the desired time period the 100 ps clock should skip 430000 cycles. And at the half way to the cycle the output pulse should change its state to give the desired pulse. This concept is coded in the VHDL and implemented using Xilinx software.

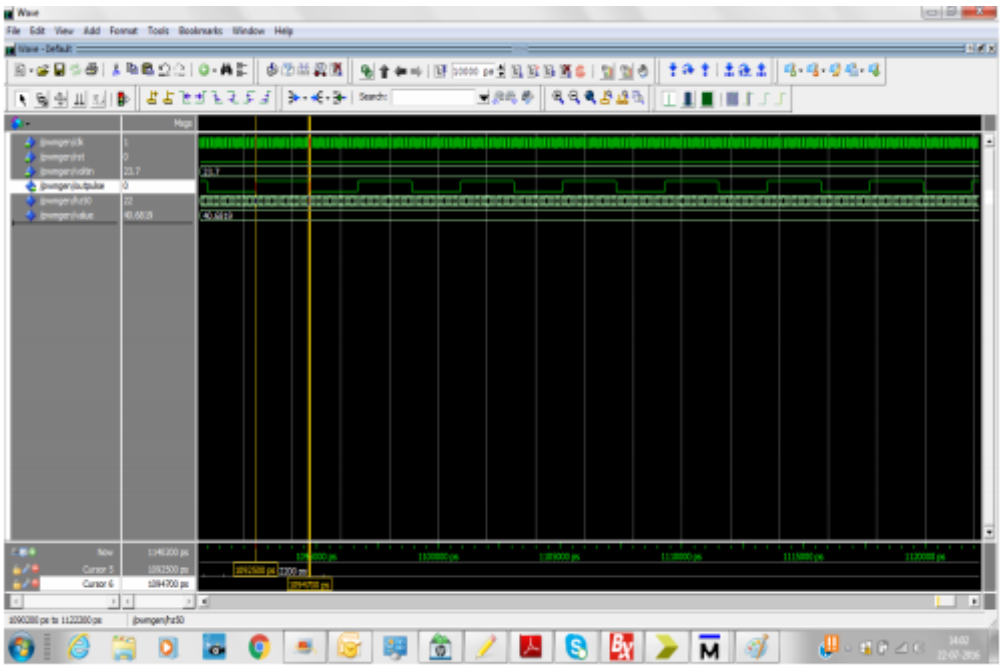
VHDL implementation for the desired hardware implementation results is shown as below

1. Output for Input of 23.6 Volts

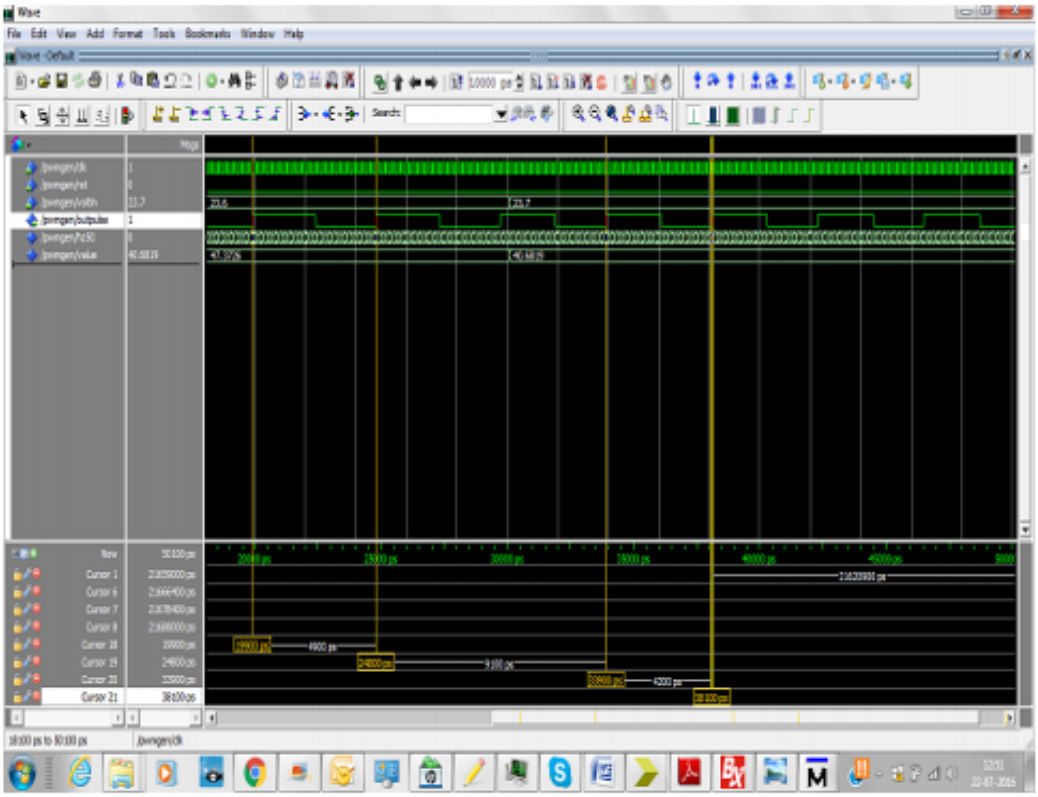


2. Output for Input of 23.7 Volts

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3. Combined output for 23.6V and 23.7 V Input



Changes can be observed in the pulse frequency on change in input voltage.

CONCLUSION

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In this paper a novel approach to Grid linked PV Inverter is presented using dual boost converter circuit.

The above work shows the implementation of a hybrid model of boost converter for inverter. Results shown above are simulated using MATLAB and Xilinx ISE software. Work done on VHDL opens up the path for customized IC production for the novel boost converter approach and provides us the flexibility to reduce the time to market for the advance and hybrid inverter technology. Furthermore as since the VHDL design is targeted for the FPGA device (field Programmable gate array) , any change in the architecture of the IC design can be done using the field programming ability of the FPGA device hence providing the solution for real time changes in the architecture as per the feedback from the Solar panel output.

FUTURE SCOPE

In addition to simulated design solutions, a real time hardware solution can be made further. For this the same design can further be extended with advance FPGA solutions providing in built processor and microcontroller architecture.

Floating point architecture of such processor provides us the path to implement the design with more accurate result

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