International journal of advances in engineering and management (IJAEM)
Volume 3, issue 6 June 2021, pp: 1864-1873 www.ijaem.net ISSN: 2395-5252

# A Interleaved Boost Converter with Voltage Multiplier And Inductor For Renewable Energy

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Submitted: 05-06-2021 Revised: 18-06-2021 Accepted: 20-06-2021

**ABSTRACT:** This paper presents a interleaved boostconverterwithvoltagemultipliermodule.Throughavoltage multiplier module composed of switched capacitorsandcoupledinductors,aconventionalinterleavedboostconverter obtains high step-up gain without operating atextremedutyratio.Highboostdc-dcconvertersplayanimportantroleinrenewableenergysourcessuchasfuelenergysystems,DC-backupenergysystemforUPS,highintensitydischargelampandautomobileapplications.Renewable energy sources such as photovoltaic energy areavailableinbothcleanandeconomicalduetonewadvancementintechnologyanduseofgoodandefficientcells.Theconfigurationoftheproposedconverternotonlyreducesthecurrentstressbutalsoconstrainstheinputcurrentripple,whichdecreasestheconductionlossesandlengthensthelifetime of the input source. DC power can be converted into ACpower at desired output voltage and frequency by using aninverter.Thecoupledinductorscanbedesignedtoextendstep-upgain,andtheswitchedcapacitorsofferextravoltageconversionratio.Hence,largevoltagespikesacrossthemainswitches are alleviated, and the efficiency is improved. Thehigh step-up conversion may require two-stage converterswithcascadestructureforenoughstep-upgain,whichdecreases the efficiency and increases the cost. Thus, a highstep-upconverterisseenasanimportantstageinthesystem

## I. INTRODUCTION

The global electrical energy consumption is steadily rising and consequently there is a demand to increase the power generation capacity without harming the environment. Renewable energy sources are the best options due to their effective operation and also they do not pollute the environment, the way burning the fossil fuels does. Solar power generation system tops the list of renewable energy sources, as the other sources such as wind, hydro, tidal sources even when taken them together will not meet the demand as the solar energy source does. But for our application we need more amount of voltage than what we are getting from solar cells, to achieve this, we need to boost up the output voltage. For this purpose, we need to use Interleaved method to improve power converter performance in terms of efficiency. The Interleaved consists of several identical boost converters connected in parallel. As the output current is divided by the number of phases, the current stress on each MOSFET's is reduced. Each mosfet is switched at the same frequency but at a phase difference of 180 degrees. The desired output voltage for a given input voltage is depends on the duty ratio. For example, if the input voltage is 60V and the desired output voltage is 120V then we have to keep the duty cycle at 0.5. Since, we are using two similar inductors in the circuit this will leads to equal sharing of the input current. Here, in this proposed method two phase IBC is chosen since the ripple content reduces with increase in number of phases. But, if the number of phases increased further without much decrease in ripple content, the complexity of circuit increases very much, there by increasing the cost of implementation. Hence, as a trade-off between the ripple content and the cost complexity, number of phases are chosen as two.

## II. PRINCIPLE OF INTERLEAVED BOOST CONVERTER

In order to achieve the requirement of small volume, light weight and reliable properties, a high-power IBC is constructed, as shown in figure 1.The principle of IBC is as follows: Each phase is a boost/buck DC-DC converter, which is

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Volume 3, issue 6 June 2021, pp: 1864-1873 www.ijaem.net ISSN: 2395-5252

composed of a bridge of power switches and storage energy inductor.

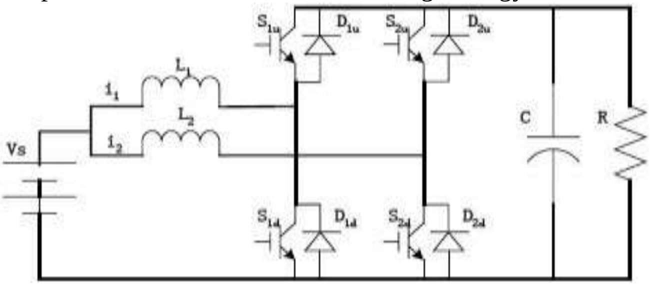


Fig 1. The topology of interleaved boost convert

When S1u=S2u=OFF, S1d and S2d switch on and off, the system works in the BOOST mode as shown in table 1.

Table. 1 The state of the power device in BOOST mode

| | | | |
|---|---|---|---|
| S1u=OFF | S2u=OFF | D1u= ON / OFF | D2u= ON / OFF |
| S1d= ON / OFF | S2d= ON / OFF | D1d=OFF | D2d=OFF |

From the table 1, it can be seen that in Boost mode, only the power devices (S1d,S2d,D1u,D2u) have switching commutation, the power devices (S1u,S2u,D1d, D2d) have no commutation. The power switches S1d and S2d have180- degree phase difference of driving pulses in a cycle. The current fluctuation of input power supply is reduced greatly because the two 180-degree phase difference inductor currents minify the fluctuation of each other. In one switching cycle Ts, considering the commutation of power switches and diodes (S1d,S2d,D1u,D2u), there are eight kinds of running states as shown in table 2.

Table. 2 The eight running states in interleaved BOOST mode

| | S1d=on | S2d=on | D1u=on | D2u=on |
|---|---|---|---|---|
| S1d=on | State 2 | State 7 | * | State 1 |
| S2d=on | State 7 | State 5 | State 4 | * |
| D1u=on | * | State 4 | State 3 | State 8 |
| D2u=on | State 1 | * | State8 | State 6 |

IBC mainly used for renewable energy sources has a number of boost converters connected in parallel which have the same frequency and phase shift. These IBC`s are distinguished from the conventional boost converters by critical operation mode, discontinuous conduction mode (DCM) and continuous conduction mode (CCM) so that the devices are turned on when the current through the boost rectifier is zero. In the CCM, the design becomes tedious as the critical point varies with load. In the DCM, the difficulties of the reverse recovery effects are taken care but it leads to high input current and conduction losses and it is not best suited for high power applications. CCM has lower input peak current, less conduction losses and can be used for high power applications. By dividing the output current into ‘n’ paths higher efficiency is achieved and eventually the copper losses and the inductor losses are reduced.

Firstly, when the device S1 is turned ON, the current in the inductor iL1 increases linearly. During this period energy is stored in the inductor L1. When S1 is turned OFF, diode D1 conducts and the stored energy in the inductor ramps down with a slope based on the difference between the input and output voltage. The inductor starts to discharge and transfer the current via the diode to the load. After a half switching cycle of S1, S2 is also turned ON completing the same cycle of events. Since both the power channels are combined at the output capacitor, the effective

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ripple frequency is twice than that of a single-phase boost converter. The amplitude of the input current ripple is small. This advantage makes this topology very attractive for the renewable sources of energy.

The gating pulses of the two devices are shifted by a phase difference of 360/n, where n is the number of parallel boost converters connected in parallel. For a two-phase interleaved boost converter n=2, which is 180 degrees and it is shown in figure 2.

The two phases of the converter are driven 180 degrees out of phase, this is because the phase shift to be provided depends on the number of phases given by 360/n where n stands for the number of phases.

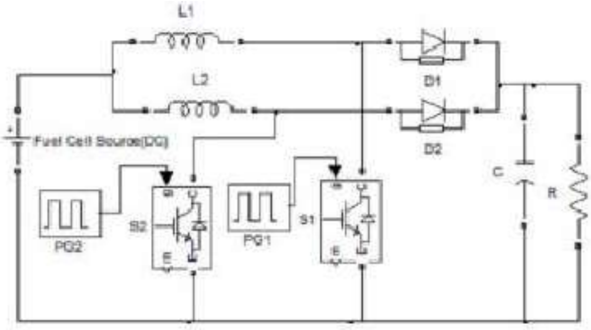


Fig. 2 Circuit diagram of a two phase uncoupled IBC

Since two phases are used the ripple frequency is doubled and results in reduction of voltage ripple at the output side. The input current ripple is also reduced by this arrangement. When gate pulse is given to the first phase for a time tJ, the current across the inductor rises and energy is stored in the inductor. When the device in the first phase is turned OFF, the energy stored is transferred to the load through the output diode D. The inductor and the capacitor serve as voltage sources to extend the voltage gain and to reduce the voltage stress on the switch. The increasing current rate across the output diode is controlled by inductances in the phases. Gate pulse is given to the second phase during the time t1 to t2 when the device in the first phase is OFF. When the device in the phase two is ON the inductor charges for the same time and transfers energy to the load in a similar manner as the first phase. Therefore the two phases feed the load continuously. Fig.3.3 to 3.5 shows the schematic diagrams of the two phase interleaved boost converter with uncoupled, directly coupled and inversely coupled IBC. As the output current is divided by the number of phases, the current stress in each transistor is reduced. Each transistor is switched at the same frequency but at a phase difference of II. Switching sequences of each phase may overlap depending upon the duty ratio (D). In this case the input voltage to the IBC is 20V and the desired output voltage is 40V, therefore D has to been chosen as 0.5.

## III.METHODOLOGY OF THE WORK

A basic boostconverter converts a DC voltage to a higher DC voltage. Interleaving adds additional benefits such as reduced ripple currents in both the input and output circuits. Higher efficiency is realized by splitting the output current into two paths, substantially reducing I2R losses and inductor AC losses.

Voltagemultipliers are similar in many ways to rectifiers in that they convert AC-to-DC voltages for use in many electrical and electronic circuit applications such as in microwave ovens, strong electric field coils for cathode-ray tubes, electrostatic and high voltage test equipment, etc, where it is necessary to have a very high DC voltage generated from a relatively low AC supply.

Generally, the DC output voltage (Vdc) of a rectifier circuit is limited by the peak value of its sinusoidal input voltage. But by using combinations of rectifier diodes and capacitors together we can effectively multiply this input peak voltage to give a DC output equal to some odd or even multiple of the peak voltage value of the AC input voltage.

3.1 Operation of IBC

Since as we are using two phases the converter is driven 180 degrees out of phase, this is because the phase shift is given by 360/n. where n stands for number of phases. Hence its clear that the phase shift is depends the number of phasesused.

When gate pulse is given to the first for time t1, the currentacrosstheinductorrisesandenergyisstoredinthe inductor. When the switch s1 in the first phase turned off, the energy stored is transferred to the load through the output diode SD1. The inductor and the capacitor serve as voltage sources to extend

International journal of advances in engineering and management (IJAEM)
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the voltage and to reduce the voltage stress on the switch. The increasing current rate across the output diode is controlled by inductances the phases. Now the gate pulse is given to the second phase during the period t1 to t2 when the switch in the first phase is turned off.When the switch in the second phase turned ON the inductor charges for the same time and transfers energy to the load in the similar way as in the first phase. Therefore, two phases feed the load continuously. Thus,the proposed converter operates in continuous conduction mode.

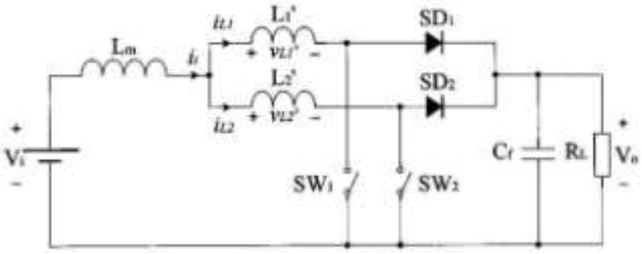


**Fig - 3:** circuit diagram of IBC

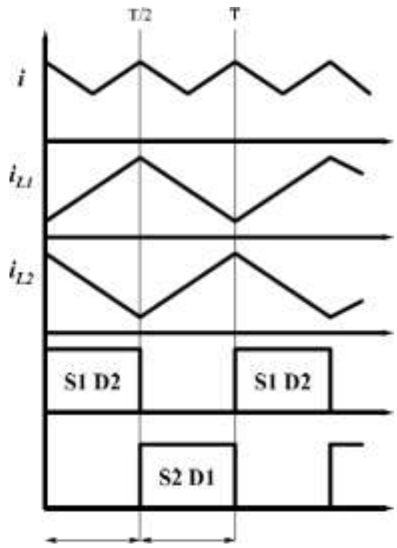


**Fig – 4:** inductor current waveforms

3.2 Operation of converter

Thestepupconverterisanon-isolatedtopologyforboostinglowvoltageinputtohighvoltageoutput.Theinputcurrentisusuallycontinuousinnatureandissuppliedtotheloadbyeithertheconductionofdiodesorcapacitors.Theboostconverterwithvoltagemultiplierbymeansofcoupledinductorinsertionincreasestheoutputvoltage,hencethe voltage gain and efficiency, with low value of dutycycle.Theoutputvoltageacrosstheloadis thesumofthevoltagefromboostconverterandthevoltagecross the voltage multiplier capacitors. The requiredduty cycle can be obtained by adjusting the voltagemultiplier, which increases the output voltage.

Thevoltagemultipliermoduleiscomposedoftwocoupledinductorsandtwoswitchedcapacitorsandisinsertedbetweenaconventionalinterleavedboostconvertertoform a modified boost–flyback–forward interleavedstructure.

Whentheswitchesturnoffbyturn,thephasewhoseswitchisinOFFstateperformsasaflybackconverter, andtheotherphasewhoseswitchisinONstateperforms asaforwardconverter.

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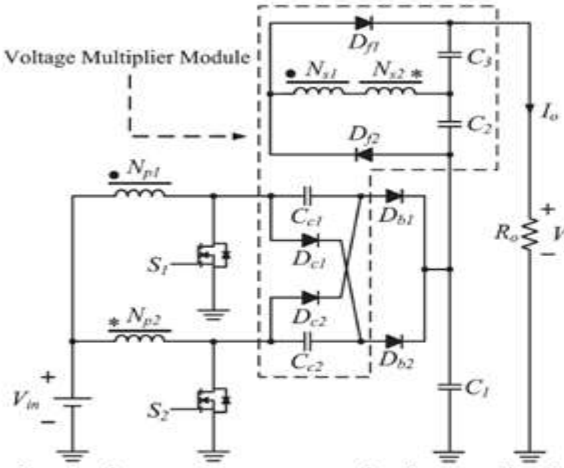


**Fig-5**:Highstepupconverterwithvoltagemultiplier

Theequivalentcircuitoftheproposedconverterisshownbelow,whereLm1andLm2arethemagnetizinginductors;Lk1andLk2representtheleakage inductors; Ls represents the series leakageinductors in the secondary side; S1 and S2 denote thepowerswitches;Cc1andCc2aretheswitchedcapacitors;andC1,C2,andC3aretheoutputcapacitors.

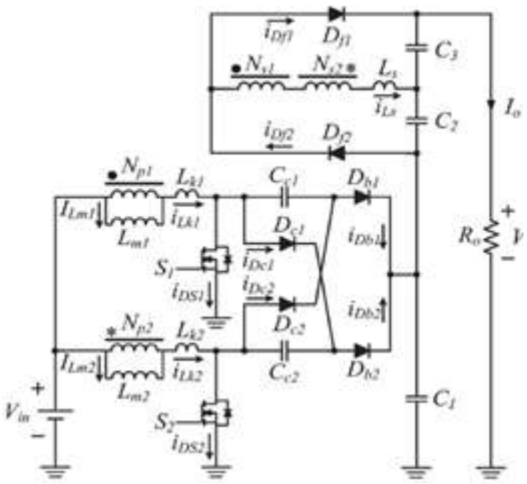

**Fig-6**:EquivalentcircuitofHighstepupconverter

WhentheswitchS1intheONstate,themagnetizinginductor,Lm1isinthechargingstate.ThereversepolarityofLm2causesdiodesDc2andDb2 forwardbiased.EnergystoredinLm2istransferredtothesecondarysideofthecoupledinductor.Thecurrentthrough the series leakage inductor, Ls flows to theoutput terminal through the output capacitor C3 andflyback forward diode. When the switch S2 in the ONstate,themagnetizinginductor,Lm2isinthechargingstate. The reverse polarity of Lm1 causes diodes Dc1andDb1forwardbiased.EnergystoredinLm1istransferredtothesecondarysideofthecoupledinductor.Thecurrentthroughtheseriesleakageinductor, Ls flows to the output terminal through theoutputcapacitorC2andflybackforwarddiode.

## IV. SIMULINKMODEL

ThesimulationisdoneonMATLABsimulink .Theoutput of the PV system is connected to the boostconverter and then to an inverter for connecting to acloads.Thesimulink modelofthe systemis shownbelow.ThePVoutputvoltagegreatlygovernedbytemperaturewhilePVoutputcurrenthasapproximatelinear relationship with solar irradiances. Due to thehighcapitalcostofPVarray,MPPTcontroltechniquesareessentialinordertoextractthemaximumavailable

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powerfromPVarrayinordertomaximizetheutilization efficiencyof PVarray

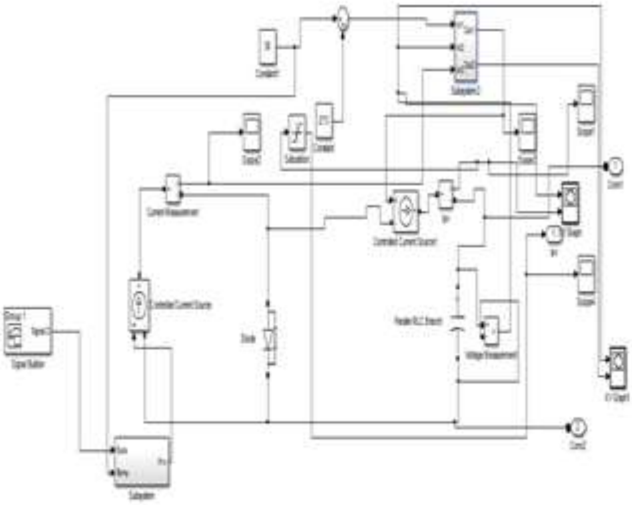

**Fig-7**:SimulinkmodelofthePVPanel

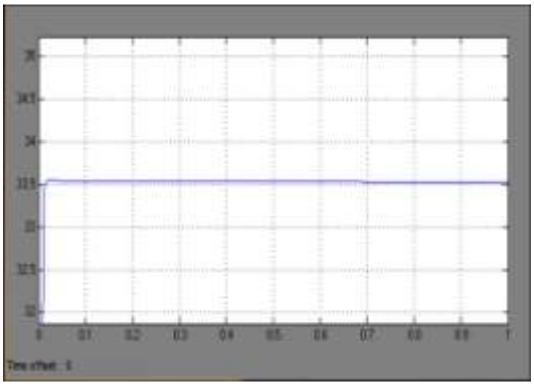

**Fig-8**:InputVoltagefromPVPanel

TheMPPTtechniqueissimulatedwiththeprincipleofP&Oalgorithm.Thesignalobtainedfromthe algorithm are given to the gate of boost converterfor the operation. The simulation model of the MPPTalgorithmwithPandOalgorithm is shownbelow.

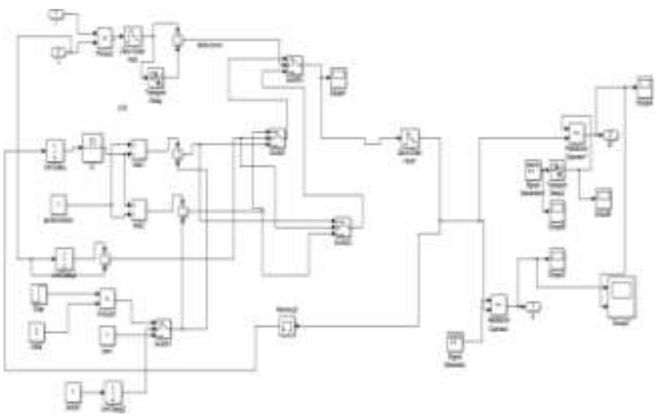

**Fig-9**:SimulinkmodeloftheMPPT

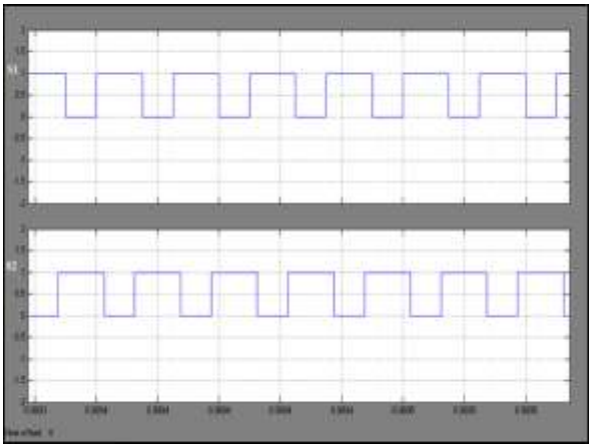

**Fig-10**: GatePulsestoSwitches

Thehighgainhighstepupconverterwithvoltage multiplier is simulated on MATLAB softwareenvironmentwithphotovoltaicsystem.Thesimulationwasdonewithaninputof30-35Vsupplytoobtainanoutputof300-400Vwithcombinationofboostconverterwithvoltage multiplier.Theinterleavedboost converter topology is designed for minimizingtheswitchinglossesandtoimprovetheefficiency.Theadvantagesofinterleavedboostconvertersaretoreducecurrentrippleandincreaseslifeof PVmodule.ThecapacitorsC2andC3aredesignedfor220µFandC1 for 470µF. The frequency is adjusted to 40 kHz bymeans of a pulse generator to obtain a gate pulse forthe both the MOSFET switches. In the simulation ofboost converter with voltage multiplier the voltageacrossloadVL,voltageacrossswitchVS,voltagesacrosscapacitorsVC1,VC2andVC3areobtained.Thedesignconsiderationofthehighboostconverterintegrationwithvoltagemultiplierincludescomponents selection and coupled inductor design.Due to the performance of high step up gain the turnsratio are set as 1:1. The boost converter with voltagemultiplier can be efficiently implemented for step upconversionwithout extremedutycycle.

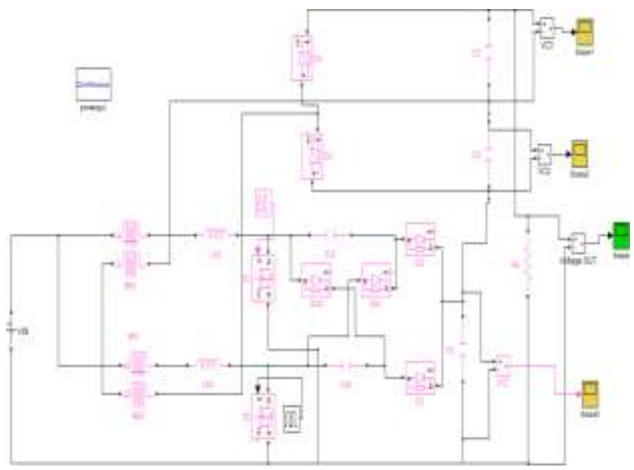

**Fig-11**:SimulinkmodeloftheHighStepupConverter

The H Bridge inverters are connected to theoutputofhighstepupconverterforconnectingittotheacloads.Thereferencesinewaveoffundamentalfrequency is compared with four carrier triangularwavesforgeneratingbasicpulsesfortheinverter.Thetriangularpulsesareselectedforafrequencyof25kHz. The basic pulses are produced by comparingthetriangularcarrierwaveswithreferencesinewaveinverter.Theoutputofconverterisgiventoamultilevel inverter for inverting the dc voltage to acvoltage.

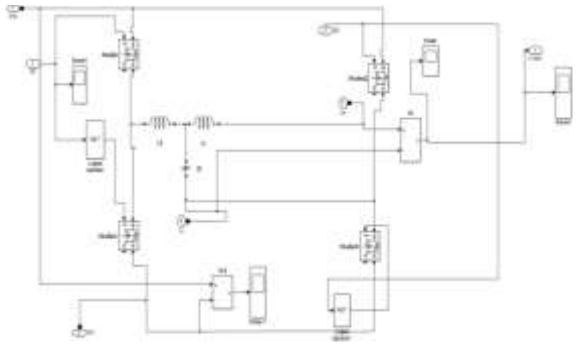

**Fig-12**:Simulink modeloftheInverter

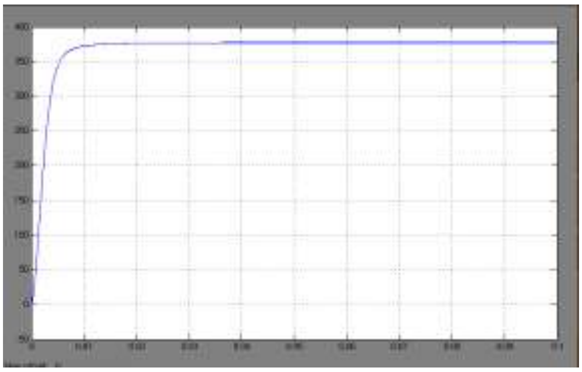

**Fig-13**:OutputvoltageoftheHighStepupConverter

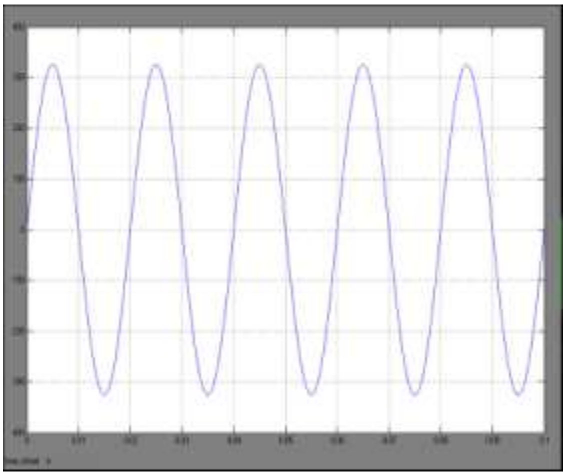

**Fig-14**:OutputvoltageoftheInverter

## V. HARDWAREIMPLEMENTATION

Prototypeforhighboostconverterwithvoltagemultiplieronintegrationwithcoupledinductorisimplemented. The converter circuit is designed usingPrintedCircuitBoard(PCB)design.PIC16F877 AmicrocontrollerisusedinthecontrollerparttogeneratePWMpulsesfortheMOSFETswitches.Aprinted circuit board, or PCB, is used to mechanicallysupportandelectricallyconnectelectronic componentsusingconductivepathways,ortraces,etchedfromcoppersheetslaminatedontoanon-conductivesubstrate. The manufacturing process consists of twomethods;printandetch,andprint,plateandetch.ThesinglesidedPCBsareusuallymadeusingtheprintandetch method. The double sided plate through -hole(PTH) boards are made by the print plate and etchmethod.

**Fig-15**: Hardwaresetupofthesystem

## VI. CONCLUSION

AHighstep-upconverterhasbeenimplementedinthispaper.Alarge voltagestep-upwithreducedvoltagestressacrossthemainswitches,important when employed in grid-connected systemsbasedonbatterystorage,likerenewableenergy systemsanduninterruptiblepowersystem applications.Othercharacteristicsoftheconverterare:voltagebalancingbetweenoutputcapacitors,lowinput-current ripple, high switching frequency, whichreducethestructurevolumeandweight,simpleswitchingcontrol,asjustasimplevoltage-loopcontrolbasedontheconventionalboostwasimplemented,andthepossibilitytomakethevoltagegainevenhigherbyincreasingthetransformerturns-ratio.Inaddition,thelossless passive clamp function recycles the leakageenergyandconstrainsalargevoltagespikeacrossthepower switch. Meanwhile, the voltage stress on thepower switch is restricted and much lower than theoutput voltage. We can extend this system to hugecommercialloadsbyincreasingthepowerratingsofPVmodule. Also we can improve monitoring by usingsuitablecurrent,voltagesensorsintothesystem.Thus,theconverterissuitableforhigh-powerorrenewableenergyapplicationsthatneedhighstep-upconversion.

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