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Multi stage interleaved voltage quadrupler Dc-Dc converter with minimum conduction loss

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ABSTRACT

A novel high step-up converter, which is suitable for renewable energy system, is proposed in this paper. In proposed system we are using three stage interleaved boost converter ,coupled inductor and voltage quadrupler concept used to reduced conduction losses, voltage spikes, voltage stress , balanced output voltage and achieve high output voltage without using extreme duty ratio and non- isolated operation. Therefore, DC boost converter is needed to boost up a dc voltage. The proposed converter cannot only achieve high step-up voltage gain with reduced component count but also reduce the voltage stress of both active switches and diodes. This will allow one to choose lower voltage rating MOSFETs and diodes to reduce both switching and conduction losses .Finally some simulation results and hardware results was given.

Key words: Boost–flyback converter, high step-up, photovoltaic (PV) system, voltage quadrupler, Interleaved converter.

I. INTRODUCTION

Now a day renewable energy plays an important role in the power system. Here solar cells and the fuel cells are increasing in nature. This solar cells are generates low voltages. This low voltage is converted in to the high enough with the usage of step-up boost converter. Fig. 1 shows a typical renewable energy system.

This block diagram consists of input PV cells, step-up converter and the load. The input Dc voltage is generated using fuel cells or PV cells. These generated voltages are normally very low. These low voltages are converted in to the high voltages for the useful applications. In order to convert this low voltage into high voltage we are using step-up converter. Some of the important step-up converters are flyback converter, cuk converter, sepic converter. The converter should provide high step-up voltage gain, low conduction losses, low input current ripple and the minimum voltage stress. A flyback converter is a simple dc-dc converter which provides high step -up voltage gain. But the switches of this converter will undergo a high voltage stress due to the leakage inductance of the transformer.

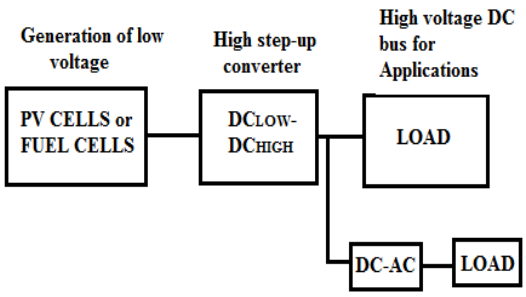

Fig.1.Typical renewable energy system

Some of the regeneration techniques are provided to reduce the voltage stress of the active switches and recycling the energy of leakage inductance. Now a days so many types of step-up converters are introduced. But these step-up converters are not suitable for high power applications due to the conduction losses of the active switches and large input current ripples. Transformer-less interleaved DC-DC converter is one method to increase efficiency of the converter and to reduce the conduction losses.

The switched capacitor-based converters proposed in (C. Evangelista, 2013; R. Li and D. Xu, 2013; L. Barote, 2013; Z. Song, 2013) which provide solutions to improve the conversion efficiency and achieve large voltage conversion ratio. Some of the single stage high step-up converters are introduced (B. R. Lin and F. Y. Hsieh, 2007; C. M. Wang, 2008; S. M. Chen, 2012; Q. Zhao and F. C. Lee, 2003; K. C. Tseng and T. J. Liang, 2004; T. J. Liang and K. C. Tseng, 2005) with high efficiency. The coupled inductor-based converter is another method to increase the high voltage gain and to decrease the conduction losses. These are proposed in (N. P.Papanikolaou and E. C. Tatakis, 2004; N. P.Papanikolaou and E. C. Tatakis, 2007). Even it provides the high voltage gain the input current ripple is relatively high which may affect the life of the capacitor.

II. PROPOSED CONVERTER

In this paper, a novel transformer-less adjustable voltage quadrupler converter along with coupled inductor topology is proposed. It integrates three phase interleaved boost converter to realize a high voltage gain and maintain the advantage of an automatic current sharing capability simultaneously. Furthermore, the voltage stress of active switches and diodes in the proposed converter can be greatly reduced to enhance overall conversion efficiency.

Fig 3 shows the circuit diagram of proposed DC-DC converter. This consists of three stages of interleaved circuit, one voltage quadrupler module. This interleaved circuit contains three coupled inductor. The primary windings of coupled inductors are Np1, Np2, Np3. The secondary windings of coupled inductors are Ns1, Ns2, Ns3. It consists of three switches S1, S2, S3. The input voltage is given from the solar panel. The interleaved converter contains three capacitors Cc1, Cc2, Cc3 and six diodes Db1, Db2, Db3, Dc1, Dc2, Dc3. The voltage quadrupler module contains five capacitors C1, C2, C3, C4, C5 and four diodes.

III.MODES OF OPERATION

In this proposed DC-DC converter there are three modes of operation.

Mode 1(S1 ON, S2 BEGINS TO OFF, S3 ON): In this mode switches S1 and S3 are remains in ON state.S2 is going to switched OFF. The current flow through Lm2 transfer the energy to secondary side of the coupled inductor and Ls flow to the output through C3, C4 and DF1. The voltage stress of S2 is clamped by the capacitor CC1 which equals to the output of the boost converter. Vin, Lm2, CC2,Db2 also releases the energy to the output. The Equivalent circuit of mode 1 is shown in the Fig 4.

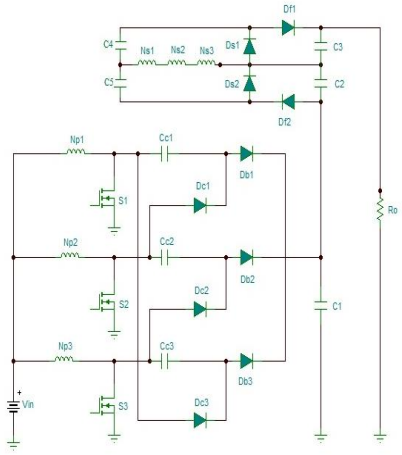

Fig.3.Three-stage interleaved boost converter

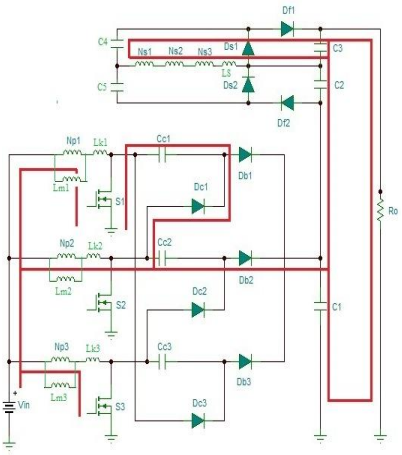

Fig.4.Equivalent circuit of mode 1

Mode 2(S1 ON, S2 ON, S3 BEGINS TO OFF): In this mode switches S1 and S2 are remains in ON state.S3 is going to switched OFF. The current flow through Lm3 transfer the energy to secondary side of the coupled inductor and Ls flow to the output through C2,C5 and DF2.The voltage stress of S3 is clamped by the capacitor CC2 which equals to the output of the boost converter.Vin,Lm3,CC3,Db3 also releases the energy to the output. The Equivalent circuit of mode 1 is shown in the Fig 5.

Mode 3(S1 BEGINS TO OFF, S2 ON, S3 ON): In this mode switches S2 and S3 are remains in ON state.S1 is begins to switch off. The current flow through Lm1 transfer the energy to secondary side of the coupled inductor and Ls flow to the output through C2, C5 and DF1. The voltage stress of S1 is clamped by the capacitor CC3 which equals to the output of the boost converter. V_{in}, Lm1, CC1, Db1 also releases the energy to the output. The Equivalent circuit of mode 1 is shown in the Fig 6.

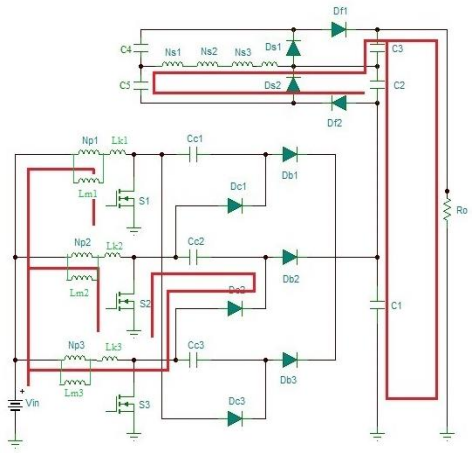

Fig.5.Equivalent circuit of mode 2

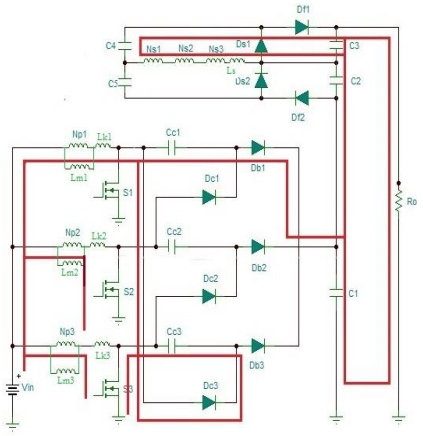

Fig.6.Equivalent circuit of mode 3

IV.SIMULATION RESULTS AND DISCUSSION

The proposed converter 18-v input voltage and 158-v output voltage fig7 is chosen .the switching frequency is used in the circuit is 20 kHz, the duty ratio of S1,S2,S3 is 0.33 so it is used to reduce voltage stress and current stress and finally it reduces conduction losses. The output voltage is increases up to 158v after it attains transient states on time period 0.6sec.

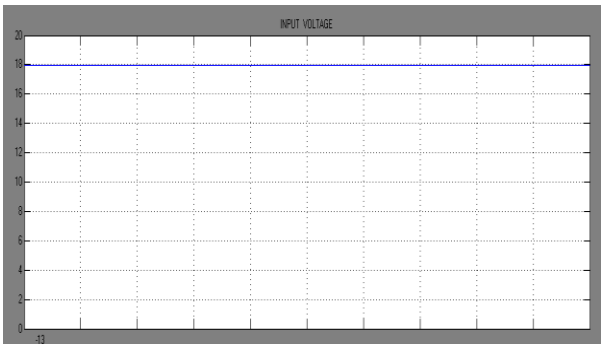

Fig 7. Input Voltage

The conduction losses on state voltage reaches attain 0.1-v the conduction of current is 6.85A.The duty ratio timing period is 0.33.

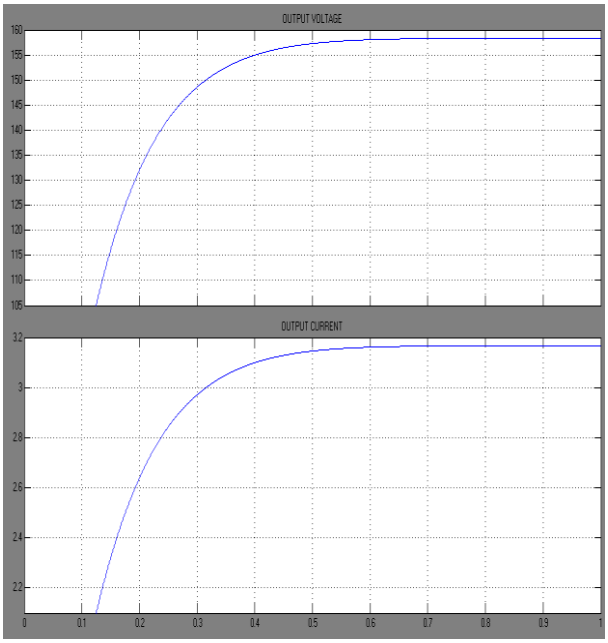

Fig 8 proposed output voltage

V.HARDWARE RESULTS AND DISCUSSION

The Hardware circuit Diagram of interleaved quadrupler dc – dc converter is shown in the Fig 9. The hardware system consists of followings modules.

- Solar panel
- Power supply module
- Control unit
- Driver unit
- Three stages of Interleaved Module
- Voltage Quadrupler Module

Solar panel: A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar module can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. An 18V solar panel is used in this system.

Power supply module: Here a 15-0-15V step down transformer is used to give the supply voltage for control circuit. This power supply module consists of rectifier circuit, filter circuit and the regulator circuit. IC 7805 regulator is used for the regulation purpose. The output of the regulator will give constant 5v Dc supply for the control circuit.

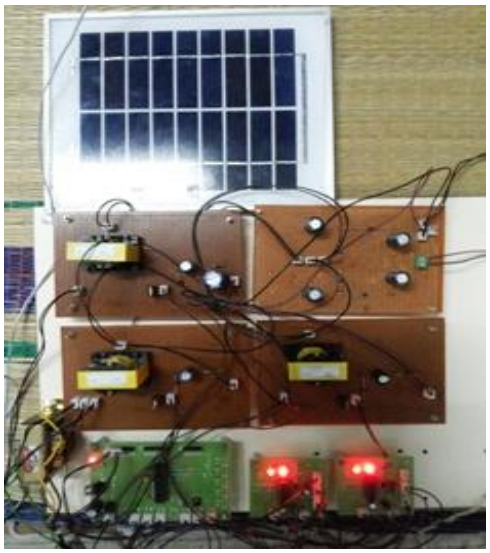

Fig.9.Hardware Circuit Diagram

Control unit: DSPIC33FJ64MC802 Microcontroller is used for producing the PWM pulses .It has Modified Harvard architecture C compiler optimized instruction set, 16-bit wide data path, 24-bit wide instructions, Flexible and powerful addressing modes. The operating range is 3-3.6V. It has low power and high speed technology.

Driver units: IRS2110 is used to drive the MOSFET. The IRS2110/IRS2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. The Chips have several applications like motor drives, lighting blast, switched mode power supplies, Automotives, Plasma Display panels. The o/p signal coming from the mc is not enough to drive MOSFET. So that this signal is converted into the high voltage signal using IRS2110.Gate drive voltage range from 10-20V

Three stages of interleaved module: This module contains three stages. Each stage consists of one coupled inductor, one MOSFET, capacitor and diodes. The current rating of the coupled inductor is 2A and the Turns ratio is 1:4.IRF840 MOSFET is used. The switching frequency of the MOSFET is 20KHZ.The capacitor range is 50V, 2200uF and the diode IN4007 is used.

Voltage quadrupler module: The voltage quadrupler module consists of four capacitors and four diodes. The three stages of interleaved converter are connected in parallel. The output of this interleaved converter is connected to the voltage quadrupler module. The capacitor range is 47uF, 250V.

Input voltage: Here the input voltage is 16.9V.It is given by the solar panel and it is measured using the multimeter.

OUTPUT VOLTAGE

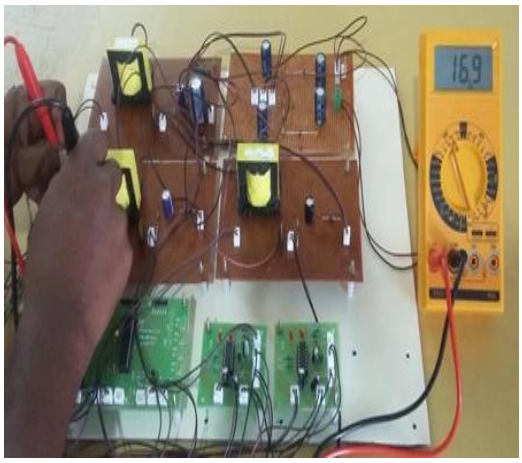

Fig.10.Input voltage

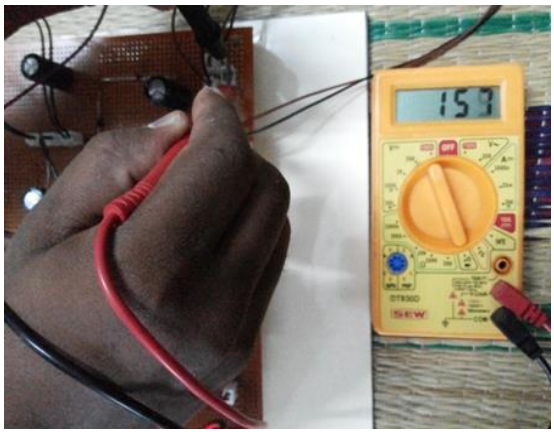

Fig.11.Output voltage

Here I am getting 157V output in the Output side of the converter which is measured by the multimeter.

CONDUCTION LOSS CALCULATION:

I/p voltage =16.9 v
O/p voltage =157v
Pon =Von Io Ton
Von =on-state voltage
Io =conducting of current
Ton =conduction during the on interval
Pon =1.98*0.07*0.33
Pon =0.046W

VI.CONCLUSION

In this paper we can achieve high output voltage and to reduce voltage stress, conduction loss by the use of three stage interleaved boost converter with coupled inductor and voltage quadrupler circuits. The hardware work depicts the effectiveness of the proposed system. High voltage conversion such as fourfold of input voltage, Minimized voltage stress on switching devices, Minimized conduction losses, Balanced output, Minimized current ripple With the help of interleaved boost converter and voltage quadrupler.

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