IJSRD - International Journal for Scientific Research & Development| Vol. 4, Issue 09, 2016 | ISSN (online): 2321-0613

Comparative approach of Two-Inductor and Cascade Boost Converter for Improved Voltages

Prem Narayan[1] B.K. Singh[2] K.S.Verma[3]
[1]Student [2,3]Assistant Professor
[1,2,3]Department of Electronics & Electrical Engineering
[1]Rajkiya Engineering College, Ambedkarnagar (U. P.), India [2]KEC, Dwarahat (Uttarakhand), India
[3]KNIT, Sultanpur (U. P.), India

Abstract— The DC-DC converter topologies have been widely used for high power and high performance applications from last few years. The advantages of DC-DC boost converters include increased efficiency, reduced size, faster transient response of system and improved reliability. The results of cascade boost converter are compared with two inductor boost converter. This paper compares the output waveform and the working of the two inductor boost converter and cascade boost converter used for fuel-cell and solar system applications. These are used for boosting the level of DC voltages.

Key words: DC-DC Converter, Boost Converter, Fuel-Cell, Voltage, Efficiency

I. INTRODUCTION

DC/DC converters are widely used for interconnections of two or more networks with different voltage levels. There are such different topologies, which varies in complexity of circuits, stress on used components and quality of input and output power [1]. In these types of boost converter are used to boost the low variable dc voltage from the fuel cell / battery and provide the high quality, regulated dc voltage to the output. From last decades isolated topologies with high frequency step-up transformer have been used commonly in the boost converter topologies.

A cleaner energy future depends on the development of alternative energy technologies to meet the world's growing energy needs but that also mitigate carbon dioxide emissions. Some of sustainable energy based power plants, including hydro, geothermal, biofuel-plants, use synchronous generators directly connected to the grid. But some other sources like fuel cells (FC) and photovoltaic (PV) basically produce a dc voltage. Such systems which have a large scope of small scale of implementation produce dc voltage which is much lower for direct implementation. So, an interface between the source and load is a need and the power electronic converter is the interface [2].

A non-isolated two-inductor boost converter consists of a common ground both for the input as well as for output, i.e. absent the electrical isolation. The two inductor boost converter exhibits benefits in high power applications [3], [4]. High input current is split between two inductors, thus reducing I^2R power loss in both copper windings and primary switches. Furthermore, by applying an interleaving control strategy, the input current ripple can be reduced [5].

The main obstacle of the circuit is its limited power regulation range. Inductor L_{p1} must support input voltage when-ever T_{p1} turns on. This is also true for L_{p2} and T_{p2}. Since the minimum duty ratio of each switch is 0.5, the magnetizing currents of the two inductors can't be limited. This leads to a minimum output power level. If the load demands is less than minimum power level, the output voltage increases abnormally because excessive energy has been stored in the inductors [6].

In connection with large input current, it results in a high conduction loss, this limits both efficiency and rated power of the converter topologies [7]. On the other hand the voltage gain curve becomes steeper when duty cycle increases. At one point it's fairly difficult to control the converter, while a very small variation in duty cycle δ results in a large change in the voltage gain k. This small variation in the duty cycle δ may be desired, as a response to change the operating conditions [8]. But it can be undesired, e.g. caused by delays in the driver circuit or different switching of the transistor due to the temperature or ageing.

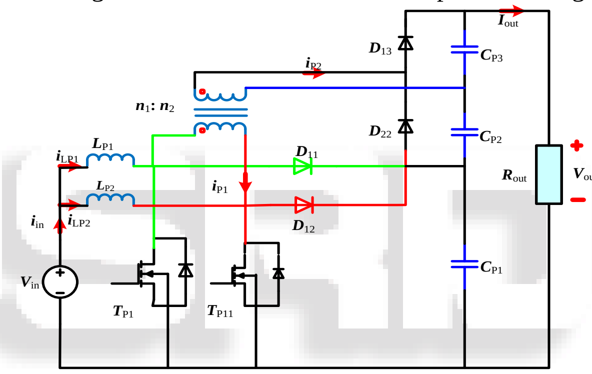

Fig. 1: Two inductor boost convertor circuit

If a very high voltage gain is required it may be more beneficial to use of two or more series connected (cascaded) boost converters, like presented on Fig. 2. This approach gives some advantages, but it creates new challenges in the same time. Main advantages include a high voltage gain, a good power decoupling between the output and the input, better utilization of semiconductors, presence of an intermediate DC bus. Major drawbacks are more complex circuit, more complex controls and a potential stability problem.

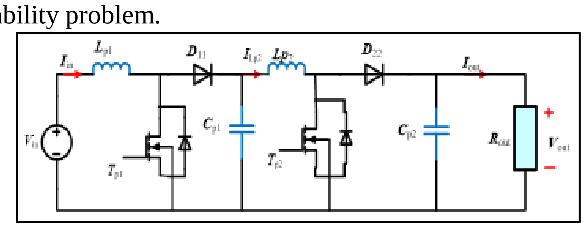

Fig. 2: Diagram of a cascaded boost converter

When a DC voltage has to be stepped up, the boost converter has long been the preferred scheme. This is because of its adjustable step-up voltage conversion ratio, continuous input current, simple topology and high efficiency. Nevertheless, when the power level increases, the inductor becomes large, bulky, costly and heavy. Also, as the required output voltage rises, conduction and switching losses increases as they are proportional to

All rights reserved by www.ijsrd.com

voltage. Sometimes, there aren't devices capable to withstand such stresses. An extensive amount of research has been carried out on these issues. Many different topological modifications have developed from this, for example: serializing switching components, cascading converters, high frequency transformer based converters and even multilevel converters either diode clamped or of the flying capacitor type. Multilevel converters have had a lot of success, especially on DC-AC applications. Some research has been made on their application on DC-DC circuits mostly of the diode clamped and the flying capacitor types. Nevertheless, a two level version of the boost converter will be very simple efficient and will have a low part count [11-17].

II. WORKING OF BOOST CONVERTER

There are four basic operational stages; stage-1 and 3 are identical. When both transistors are on the input current $i_{in(t)}$ increases and energy is stored in inductors L_{p1} and L_{p2}. The winding n_{11} is essentially shorted and no voltage induces in the winding n_{22}. All diodes are reverse biased, so the load is supplied from output capacitors. At the beginning of stage-2 the transistor T_{p1} is turned-off and the diode D_{11} starts to conduct because of continuous inductor current $i_{Lp1(t)}$. The capacitor voltage $v_{Cp1(t)}$ is being applied to the winding n_{11} and voltage $n*v_{Cp1(t)}$ induces in the winding n_{22}. If this voltage is larger than the capacitor voltage $v_{Cp3(t)}$ then the diode D_{13} become forward biased and conducts the current $i_{n2}(t)$ recharging the capacitor C_{p3}. Stage-4 is similar to stage-2 but the transistor T_{p11} is turned-off and T_{p1} remains on. Diodes D_{12} and D_{22} conduct and capacitors C_1 and C_2 are recharged during stage-4.

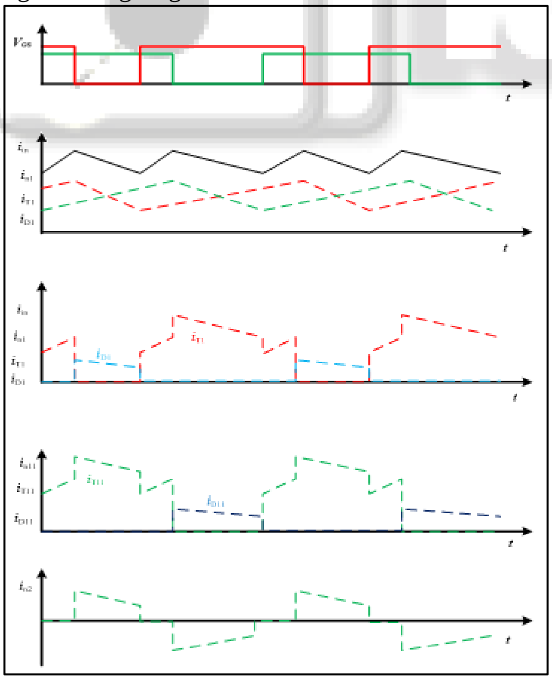

Fig. 3: Waveforms of the two-inductor boost converter

The voltage gain of this converter is given by (2). Voltage stress of transistors and diodes D_{11} and D_{12} is given by (3). Diodes D_{22} and D_{13} have to handle reverse voltage given by (4). Assuming that the inductor currents have only a very small ripple and the current $i_{p2(t)}$ is almost rectangular, the transistor rms current is found with (5). The average forward current of diodes D_{22} and D_{13} is equal to the output DC current I_{out}. The average forward current of diodes D_{11} and D_{12} equals half of the output DC current, since these diodes are connected in parallel. Required power rating of transistors and diodes is found by (6-10). The required storage inductances L_{p1} and L_{p2} are calculated by (11), while (12) gives the effective output capacitance.

$$n = \frac{n_{22}}{n_{11}} \quad (1)$$

$$k = \frac{1+2.n}{1-\delta} \quad (2)$$

$$V_{Tp1(off)} = V_{Tp11(off)} = V_{D11(R)} = V_{D12(R)} = \frac{1}{1+2.n} . V_{out} \quad (3)$$

$$V_{D22(R)} = V_{D13(R)} = \frac{2.n}{1+2.n} . V_{out} \quad (4)$$

$$I_{Tp1(rms)} \approx \sqrt{(1-\delta).\left(\frac{k.I_{out}}{2} + n.\frac{I_{out}}{1-\delta}\right)^2 + (2\delta-1).\left(\frac{k.I_{out}}{2}\right)^2} \quad (5)$$

$$\text{volt X amp}_{Tp1} = V_{Tp1(off)}.I_{Tp1(rms)}$$

$$\approx \frac{1}{2.n+1}.\sqrt{(1-\delta).\left(\frac{k}{2} + \frac{n}{(1-\delta)}\right)^2 + (2\delta-1).\left(\frac{k}{2}\right)^2} . P_{out} \quad (6)$$

$$\text{volt X amp}_{TT} = 2.\text{volt X amp}_{Tp1} \quad (7)$$

$$\text{volt X amp}_{D11} = \frac{1}{1+2.n} . V_{out}.\frac{I_{out}}{2} = \frac{1}{2.(1+2.n)} . P_{out} \quad (8)$$

$$\text{volt X amp}_{D22} = \frac{2.n}{2.n+1} . V_{out}.I_{out} = \frac{2.n}{2.n+1} . P_{out} \quad (9)$$

$$\text{volt X amp}_{DT} = 2.(\text{volt X amp}_{D11} + \text{volt X amp}_{D22}) = \left(\frac{4.n+1}{2.n+1}\right) . P_{out} \quad (10)$$

$$L_{p1} = L_{p2} = \frac{V_{in}.\delta}{2.\Delta i_{Lp1}.f_s} \quad (11)$$

$$C_{out} = \frac{I_{out}.\delta}{2.\Delta v_{out}.f_s} \quad (12)$$

The voltage gain of the cascaded boost converter operating in CCM is the product of the voltage gain of each stage in (13). The transistor T_{p1} and the diode D_{11} have to handle the intermediate voltage V_{C11}, while the transistor T_{p2} and the diode D_{22} have to handle the output voltage V_{out}. Transistors rms currents are given by (14) and (15), under assumption of a small input current ripple and a large intermediate ripple current. Required power rating of both transistors is the sum of respective power ratings and is given by (18). Similarly requires power rating of both diodes is given by (21). For a large voltage gain k cascading of two or more boost converters lead to a significant reduction of the required transistors power rating, but in the same time it increases required diodes power rating by number of cascaded converter stages.

$$k = k_1.k_2 = \left(\frac{1}{1-D_{11}}\right).\left(\frac{1}{1-D_{22}}\right) \quad (13)$$

$$I_{Tp1(rms)} = I_{in}.\sqrt{1+\frac{1}{3}.\left(\frac{\Delta i_{in}}{I_{in}}\right)^2} . \sqrt{D_{11}}$$

$$\approx k_1.k_2.\sqrt{D_{11}} . I_{out} \quad (14)$$

$$I_{Tp2(rms)} = I_{Lp2}.\sqrt{1+\frac{1}{3}.\left(\frac{\Delta i_{Lp2}}{I_{Lp2}}\right)^2} . \sqrt{D_{22}}$$

$$\approx k_2.\sqrt{D_{22}} . \sqrt{1+\frac{1}{3}.\left(\frac{\Delta i_{Lp2}}{I_{Lp2}}\right)^2} . I_{out} \quad (15)$$

$$volt\ X\ amp_{Tp1} = V_{Tp1(off)}.I_{Tp1(rms)}$$

$$\approx \frac{V_{out}}{k_2}.k_1.k_2.\sqrt{D_{11}} . I_{out}$$

$$= k_1.\sqrt{D_{11}}.P_{out} \quad (16)$$

$$volt\ X\ amp_{Tp2} = V_{Tp2(off)}.I_{Tp2(rms)}$$

All rights reserved by www.ijsrd.com

$$\approx V_{out}.k_2.\sqrt{D_{22}}\sqrt{1+\frac{1}{3}.\left(\frac{\Delta i_{Lp2}}{I_{Lp2}}\right)^2}.I_{out}$$

$$= k_2.\sqrt{D_{22}}\sqrt{1+\frac{1}{3}.\left(\frac{\Delta i_{Lp2}}{I_{Lp2}}\right)^2}.P_{out} \qquad (17)$$

$$volt\ X\ amp_{TT} = volt\ X\ amp_{Tp1} + volt\ X\ amp_{Tp2}$$

$$= \left(k_1.\sqrt{D_{11}} + k_2.\sqrt{D_{22}}\sqrt{1+\frac{1}{3}.\left(\frac{\Delta i_{Lp2}}{I_{Lp2}}\right)^2}\right).P_{out} \qquad (18)$$

$$volt\ X\ amp_{D11} = \frac{V_{out}}{k_2}.I_{out} \approx P_{out} \qquad (19)$$

$$volt\ X\ amp_{D22} = V_{out}.I_{out} \approx P_{out} \qquad (20)$$

$$volt\ X\ amp_{DT} = volt\ X\ amp_{D11} + volt\ X\ amp_{D22} = 2.P_{out} \qquad (21)$$

$$L_{p1} = \frac{V_{in}.\delta}{2.\Delta i_{in}.f_{s1}} \qquad (22)$$

$$L_{p2} = \frac{V_{C1}.D_{22}}{2.\Delta i_{Lp2}.f_{s2}} \qquad (23)$$

$$C_{p1} = \frac{I_{L2}.D_{11}}{2.\Delta v_{Cp1}.f_{s1}} \qquad (24)$$

$$C_{p2} = \frac{I_{out}.D_{22}}{2.\Delta v_{out}.f_{s2}} \qquad (25)$$

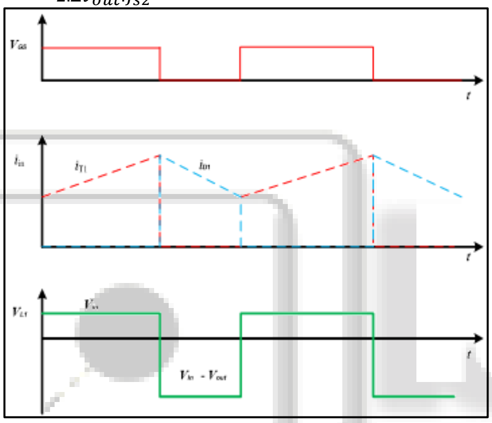

Fig. 4: Waveforms of cascade boost converter

III. Control Strategy

When designing a converter, power electronics switches are assumed to be in ideal conditions and operating at high-switching frequency. PWM generator circuit produces gating signal for the switches. It is generated by comparing the DC output of the converter and reference signal with triangular as carrier wave signal .The PWM generator circuit is shown in Fig. 5.

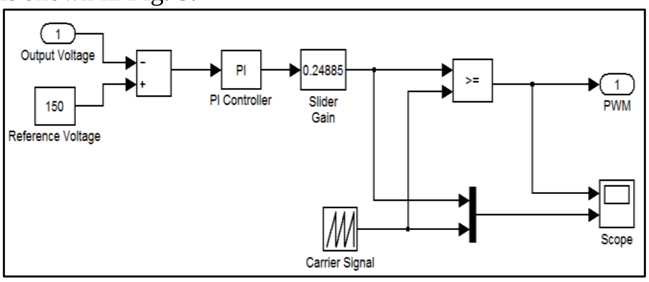

Fig. 5: Control scheme for the converters

IV. Simulation Results

The performance of the boost converter is verified via computer simulation. The simulation is conducted using MATLAB/SIMULINK software package.

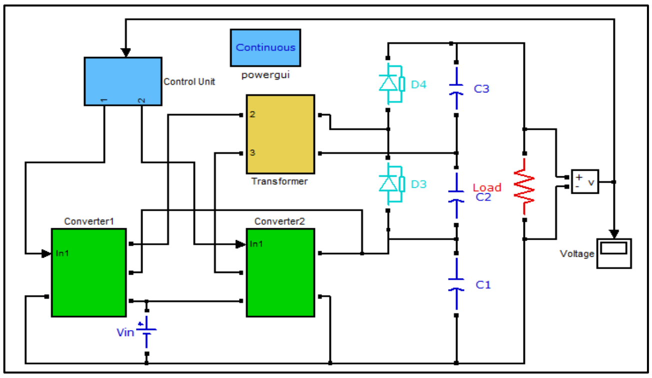

Fig. 6: Simulink diagram of two-inductor boost converter

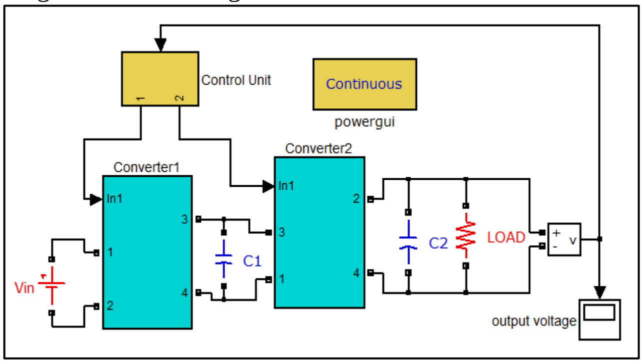

Fig. 7: Simulink diagram of cascade boost converter

A. *Analysis of the Converters*

By making use of MATLAB/SIMULINK software package the analysis of both converters are performed and results are observed.

1) *Two Inductor Boost Converter Waveforms*

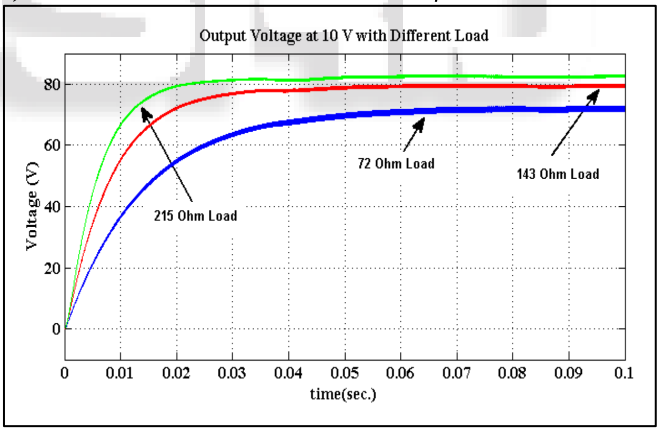

Fig. 8: Output voltage for different load at 10 V

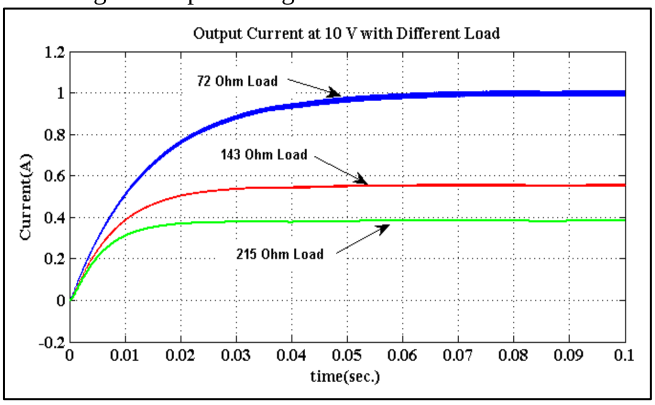

Fig. 9: Output current for different load at 10 V

All rights reserved by *www.ijsrd.com*

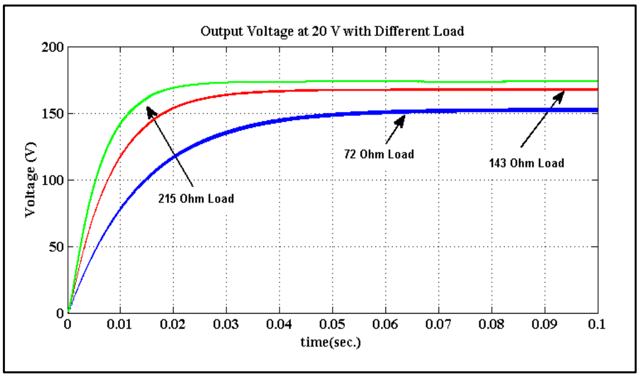

Fig. 10: Output voltage for different load at 20 V

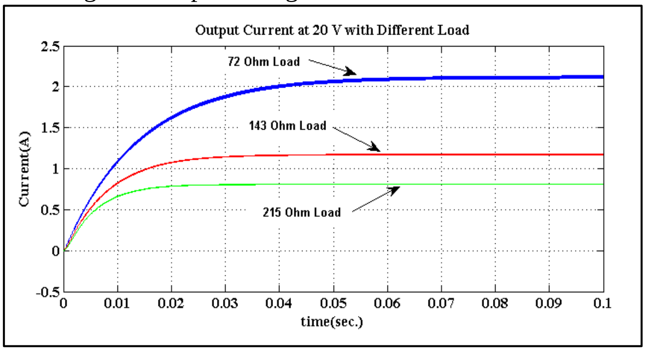

Fig. 11: Output current for different load at 20 V

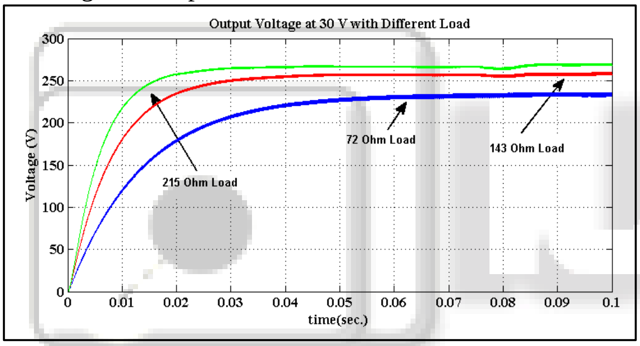

Fig. 12: Output voltage for different load at 30 V

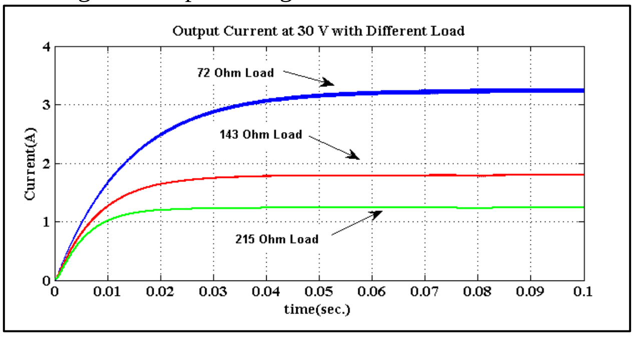

Fig. 13: Output current for different load at 30 V

2) *Cascade Boost Converter Waveforms*

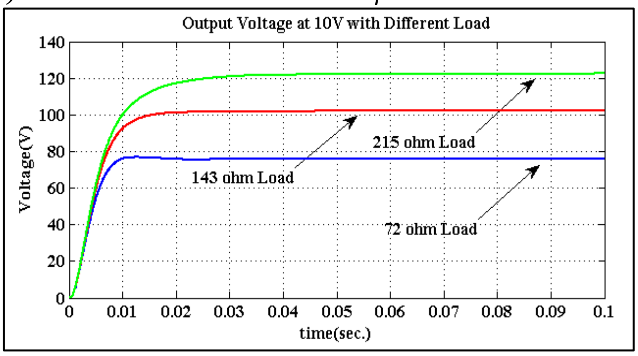

Fig. 14: Output voltage for different load at 10 V

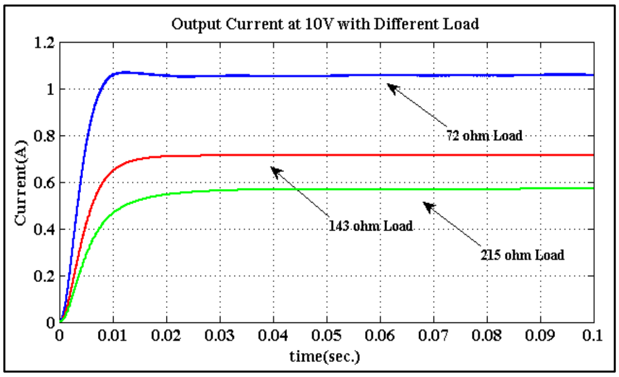

Fig. 15: Output current for different load at 10 V

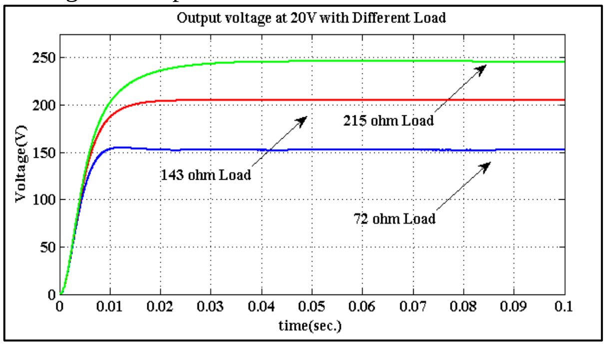

Fig. 16: Output voltage for different load at 20 V

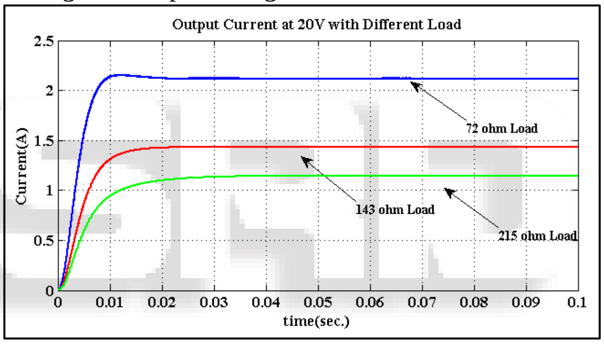

Fig. 17: Output current for different load at 20 V

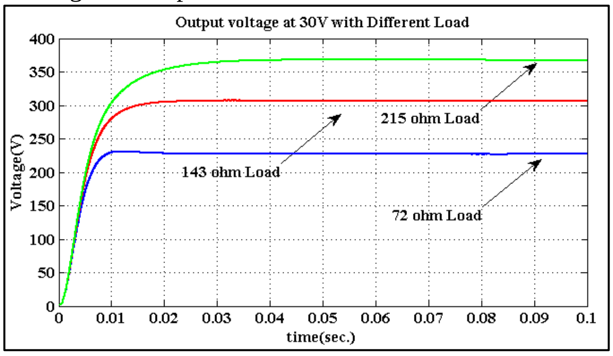

Fig. 18: Output voltage for different load at 30 V

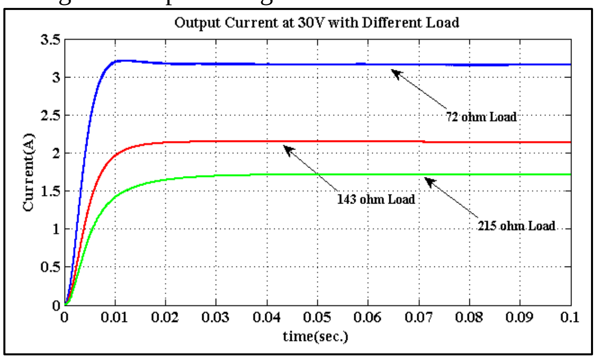

Fig. 19: Output current for different load at 30 V

All rights reserved by *www.ijsrd.com*

The performance of the non-isolated two-inductor and cascade boost converter system with R load in tabular form is shown in Table I, Where three input voltages (10 V, 20 V and 30 V) and three resistive loads (72 Ω, 143 Ω and 215 Ω) are used for analysis of the converters. Performance of the converters according to the output voltage, current and efficiency of the system are calculated and analyzed.

S. No.	V_{in} (V)	Load (Ω)	Output Current (A)		Output Voltage (V)		Efficiency	
			Two Inductor	Cascade	Two Inductor	Cascade	Two Inductor	Cascade
1	10	72	0.991	1.06	71.31	76.02	71.34	85.23
2	10	143	0.551	0.72	78.79	102.2	72.40	85.33
3	10	215	0.381	0.57	81.91	122.4	70.49	84.94
4	20	72	2.109	2.12	151.8	152.3	76.58	87.47
5	20	143	1.166	1.43	166.8	205	77.64	87.10
6	20	215	0.804	1.14	172.9	245.8	75.52	86.50
7	30	72	3.229	3.15	232.5	226.9	78.12	88.12
8	30	143	1.777	2.14	254.1	305.9	77.79	87.62
9	30	215	1.247	1.71	268.1	367.3	77.01	86.86

Table 1: Performance Comparison of Converters

The comparison of the converters is shown by the graph below, which includes waveforms of voltage, current and efficiency of the system. By this the comparisons of the converters takes place and analysis is done by these waveforms.

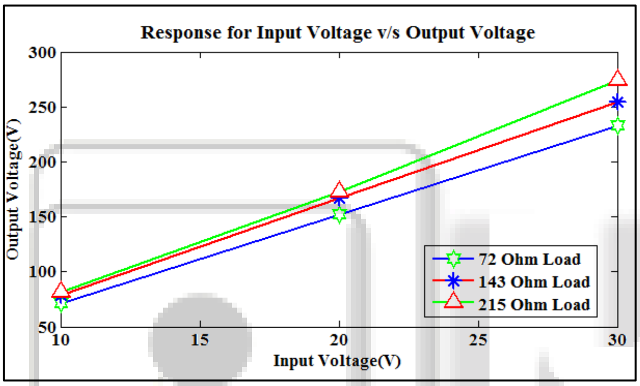

Fig. 20: Response of two-inductor boost converter with input

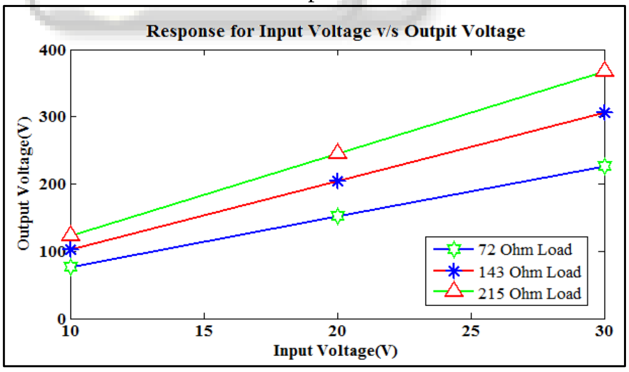

Fig. 21: Response of cascade boost converter with input

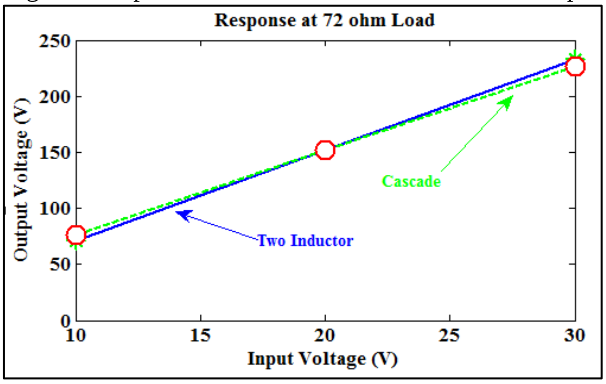

Fig. 22: Response of the converters at 72 ohm Load

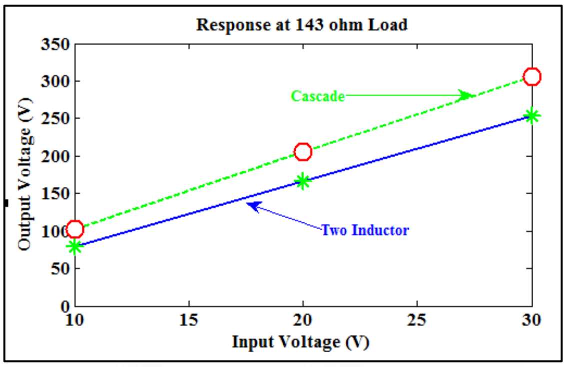

Fig. 23: Response of the converters at 143 ohm Load

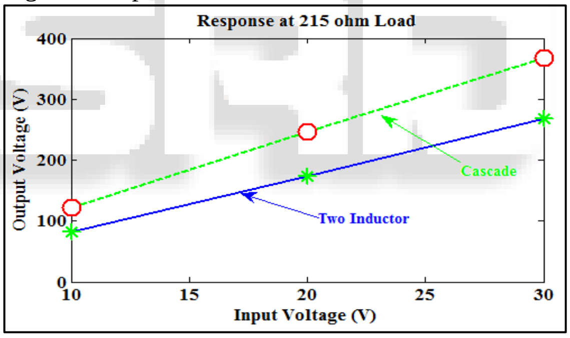

Fig. 24: Response of the converters at 215 ohm Load

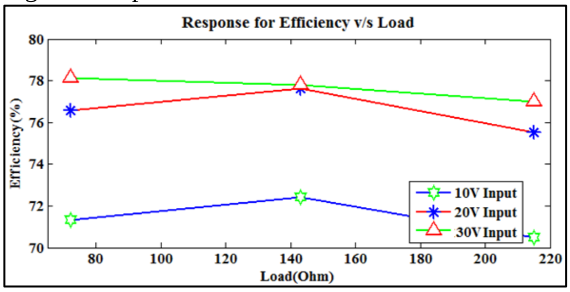

Fig. 25: Efficiency response of two-inductor boost converter

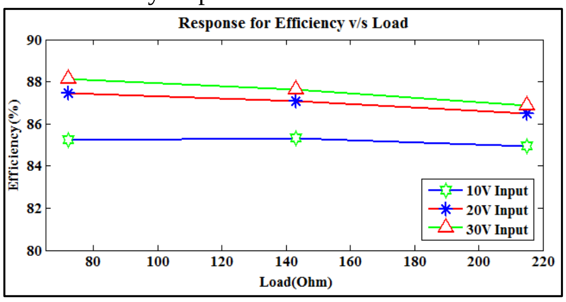

Fig. 26: Efficiency response of cascade boost converter

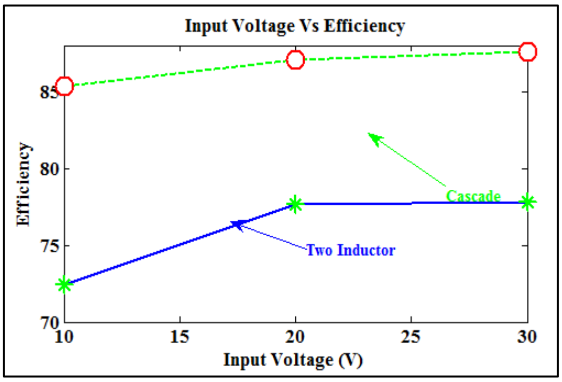

Fig. 27: Efficiency response of the both converters

From the above Table I it is to be discussed that how the system output voltage and efficiency varied according to the input voltage and load. The variation in output voltage and efficiency is shown in Fig. 20 to Fig. 27.

V. CONCLUSIONS

At low load both converters have nearly same output voltages for any value of input voltages. As the load increases the output voltage respect to the load increases. The output voltage is more in case of cascade boost converter in comparison to two-inductor boost converter. By increasing the input voltage efficiency is also increased in both converters. Efficiency of cascade boost converter is higher than the two-inductor boost converter at any load with input voltage.

In future it can be used with the solar cell to provide power for the electrical vehicles. It gives good performance at every level of the load. It reduces the space of storage and number of the battery also, which is more economical.

REFERENCES

[1] P. Klimczak and P. Munk-Nielsen "A single switch dual output non-isolated boost converter," in APEC 2008, Twenty-Third Annual IEEE, 2008, pp. 43-47
[2] Y. Jang, M. M. Jovanovic, "New two-inductor boost converter with auxiliary transformer," IEEE APEC'02 Conf, PP: 654–660, 2002.
[3] B. A. Miwa, D. M. Otten, and M. F. Schlecht, "High efficiency power factor correction using interleaving techniques," IEEE APEC Conf., pp. 557–568, 1994.
[4] P. J. Wolfs, "A current-sourced dc–dc converter derived via the duality Principle from the half bridge converter," IEEE Trans. Ind. Electron., Vol.40, No.1, pp. 139-144, 1993.
[5] M. S. Elmore, "Input current ripple cancellation in synchronized, parallel connected critically continuous boost converters," IEEE APEC Conf., pp. 152–158, 1996.
[6] W. Rong-Jong and D. Rou-Yong, "High step-up converter with coupled inductor, "Power Electronics, IEEE Transactions on, vol. 20, pp. 1025-1035, 2005
[7] Y. Kanthaphayao and C. Boonmee "Dual-output DC-DC power supply without transformer" in TENCON 2004. 2004 IEEE Region 10 Conference 2004, pp. 41-44 Vol. 4
[8] Z. Qun and F. C. Lee, "High-efficiency, high step-up DC-DC converters, "Power Electronics, IEEE Transactions on, volume 18, pp. 65-73, 2003
[9] D. M. Van de Sype, K. De Gusseme, B. Renders, A. R. Van den Bossche, and J. A. Melkebeek, "A single switch boost converter with a high conversion ratio," in APEC 2005. Twentieth Annual IEEE, 2005, pp. 1581-1587 Vol. 3
[10] Rashid M. H., "Power Electronics, Circuits, Devices, and Applications", Third Edition, Pearson Education, Inc., 2004.
[11] F. L. Luo, "Positive output Luo converters: voltage lift technique," Electric Power Applications, IEE Proceedings -, vol. 146, pp. 415-432, 1999.
[12] F. L. Y. H. Luo, Advanced DC/DC converters. Boca Raton: CRC Press, 2004.
[13] B. Farhangi and S. Farhangi, "Comparison of z-source and boost-buck inverter topologies as a single phase transformer-less photovoltaic grid-connected power conditioner" in Power Electronics Specialists Conference, 2006 PESC 06, 37th IEEE, 2006, pp. 1-6.
[14] L. Poh Chiang, D. M. Vilathgamuwa, Y. S. Lai, C. Geok Tin, and Y. Li, "Pulse width modulation of Z-source inverters," Power Electronics, IEEE Transactions on, vol. 20, pp. 1346-1355, 2005.
[15] L. Shiguo, Y. Zhihong, L. Ray-Lee, and F. C. Lee, "A classification and evaluation of paralleling methods for power supply modules" in Power Electronics Specialists Conference, 1999. PESC 99, 30th Annual IEEE, 1999, pp. 901-908 vol.2
[16] L. Po-Wa, L. Yim-Shu, D. K. W. Cheng, and L. Xiu-Cheng, "Steady-state analysis of an interleaved boost converter with coupled inductors," Industrial Electronics, IEEE Transactions on, vol. 47, pp. 787-795, 2000.
[17] W. Wei and L. Yim-Shu, "A two-channel interleaved boost converter with reduced core loss and copper loss," in Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual, 2004, pp. 1003-1009 Vol. 2.