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A Novel Transfromerless Interleaved Buck Converter with Minimum Switching Stresses and Improved Conversion Ratio

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Abstract— **this paper presents a two high step down based DC to DC converter has been suggested to investigating with various control approaches for retaining the voltage and current. The suggested converters have developed by transfromerless and having equivalent power ratings. Two diverse switching patterns are utilized in this study for mitigating the stresses across switches in the proposed system. The very first switching pattern is consisted of pulse width modulation (PWM) and 180^{0} phase shift angle along with LC filter in output side. This system can be operated in closed loop due to adding the LC filter in output side. The first designed converters duty cycle will be greater range and less than 0.5. For second DC-DC converter has been designed and implemented with second switching pattern for sustaining the voltage and duty cycles with LC filter in output side. In this stage, the sums of stress voltage on their switches are quite high as compared with the first designed converter. The proposed system is designed establishing MATLAB/Simulink as well as investigated in all operating circumstances. As per the simulation outcomes, the proposed closed loop system with LC filter can be shown the high performance in all dynamic operating situations.. The proposed converters will be analyzed for all in their switching patterns. In order to validate the results from theoretical, the 1st and 2nd proposed converters for 500/26 and 800/20.5 V, respectively, and 430 W, are used in MATLAB/Simulink.**

Keywords— DC to DC converter, LC filter, voltage, duty cycle, and current.

I. INTRODUCTION

The DC-DC converters are divided into two types based on voltage level and high current ratings which can be known as buck converters have different applications, for example, in, voltage controller modules, chip, chargers of electrical cars, light-discharging diode drivers, battery chargers and furthermore in electroplating wherein great momentum thickness is needed for the DC electrolysis measure [1 to5]. The fundamental compel of the regular step down converters would be the amazingly thin preselected duty ratio to get lesser voltage(V) transformation proportions which could cause extreme voltage stress across diodes and switches, subsequently, the connected misfortunes could be expanded in [6 & 7]. To give decrease voltages (V) and better yield flows through DC to DC step down converters (BC) without obliges of the customary step down converters (BC), a few buck converters (BC) have been introduced lately. DC to DC step down converters dependent on transformers or Coupled Inductors (CI) could be a decent decision to build the yield flows. In [8–12], the buck converters are introduced which are dependent on CI.

In [8] a two-stage super high step down Direct current converter was introduced. In addition a tapped inductor buck DC to DC converter with a CI is introduced in [9]. A step down converter with a more extensive voltage change proportion is introduced in [10]. In [11] a voltage controller with a flyback structure is introduced, which uses a transformer to diminish the information voltage. In addition, a CI-based converter was introduced in [12], in which the dimensions of the center were considered. By lowering the turn-around proportion of the optional windings of the CI's in those converters, the yield voltage will be reduced more [13].Be that as it may, the dc to dc converters with CI in their constructions experience the ill effects of spillage inductances [l], which may source great voltage stress on semi-conductor components and may source great information current waves, which may effectively affect sustainable power change units.

To maintain a strategic distance from the downsides of executing transfromerless converters, coupled inductors are introduced. The transfromerless DC–DC step down geographies are introduced in [14, 15]. A transfromerless three-stage DC to DC bi-directional converter for auto applications is introduced in [16]. An additional great decision to accomplish high step down change proportions without applying very thin obligation proportions for controlling the dynamic switches could be exchanged inductor and exchanged capacitor based (or) receiving a mix of those components to give decrease yield voltages and greater flows at yield terminals. By including additional cells, consisting of diodes, inductors (or) capacitors, the transformation proportion of the converter could be more enhanced [17]. Notwithstanding, the primary disadvantage of those converters, equivalent to different transfromerless converters introduced within [14 to16], could be circuit components and various cells required to give excessive transformation proportions, which cause more misfortunes. The high voltage transformation proportion bi-directional converter has been introduced in [18 to 21], which may be implemented as step down converters. Those converters experience the ill effects of obliges of the CI's, for example, excessive current anxieties and voltage spikes on semi-conductors due to spillage inductance in their geographies.

Quadratic DC to DC step down converters (QBC) are reasonable decisions to give enhanced change proportions without picking incredibly tight duty ratios, a great amount of parts and without using transformers. A QBC is introduced in [22]. In order to progress the change proportion of the QBC, a switch capacitor cellular is introduced to its geography [23]. Likewise, in [24], a semi-QBC is introduced. The principle compel of the converters of this kind is the high-voltage stress of their semi-conductor components. Interleaved structures type step down converters are introduced to diminish the voltage stress in step down converters, as of late. In [25& 26], traditional interleaved converters are introduced. Besides, in [27 to 31], other transformer less step down DC to DC converters with interleaved constructions and exchanging designs are introduced. In any case, the primary disadvantage that the converters with interleaved exchanging design are confron.

In this work, a novel two high step down based Direct Current to Direct Current converter has been suggested to investigating with various control approaches for retaining the voltage and current. The suggested converters have developed by transfromerless and having equivalent power ratings. Two diverse switching patterns are utilized in this study for mitigating the switches in the proposed system. The proposed system has been designed using MATLAB/Simulink and investigated in all operating circumstances. As per the simulation outcomes, the proposed closed loop system with LC filter can be shown the high performance in all dynamic operating situations.

II. Methodology

The suggested high step down converters with comparable circuits during switching stages are shown in Figures. 1 and 2, individually. In Figure. 1A, the applied exchanging design is interleaved with 180° phase shift, at that point, there will be two transformation proportions for duty ratios bigger and less than 0.5. In light of the way that the transformation proportion of the converter for duty ratio<0.5 is better, subsequently, the change proportion of the 1st converter for the interleaved exchanging design is introduced for duty proportions <0.5. Then again, the construction introduced in Figure. 2A is worked with the subsequent exchanging design, which has a solitary transformation proportion for the entire scope of duty cycles. The force circuits of the 1st and 2nd suggested converters in quite a while. 1a and 2a have two switches S_a, S_b. Note that in 2nd exchanging design, the beat entryways of switches are inverse with one another, as such, when switches of one kind is 'ON' the other is 'OFF'. Thus, this applied exchanging design is straightforward. Nevertheless, these converters have 4 inductors of L_{1a}, L_{2a}, L_{1b}, and L_{2b}.Furthermore, these converters have diodes D_{1a}, D_{2a}, D_{3a}, D_{4a}, $D_{5a}$and D_{6a}in the upper module and D_{1b}, D_{2b}, D_{3b}, D_{4b}, $D_{5b}$and D_{6b}in the bottom module, the capacitors C_{1a}, C_{2a}, C_{3a}in the upper module and C_{1b}, $C_{2b}$and C_{3b}in the bottom module. Note that the applied capacitors are assumed big sufficient, besides, the voltages throughout them are taken into consideration to be consistent values. The converters proposed are analyzed below continuous conduction modes. The different modes of the circuit as shown in [32].

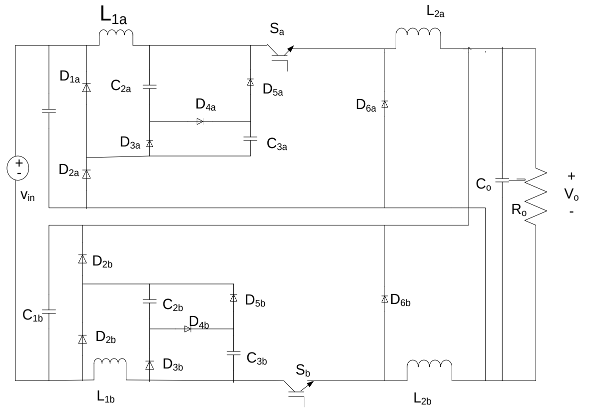


Fig: A. Equivalent circuit of first converter [32].

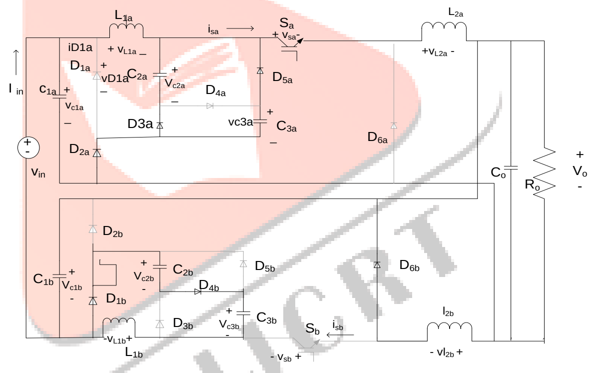


Fig:B . First mode [32].

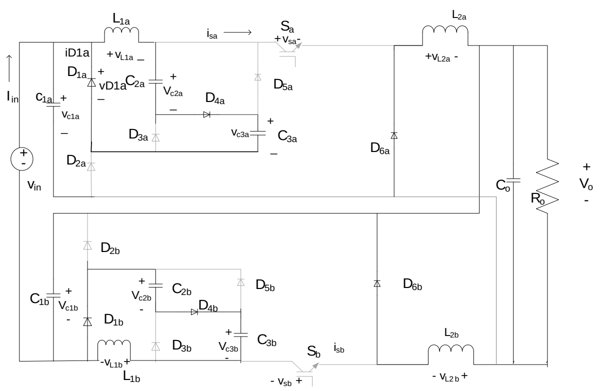


Fig:C. The 4th and 2ndmodes [32].

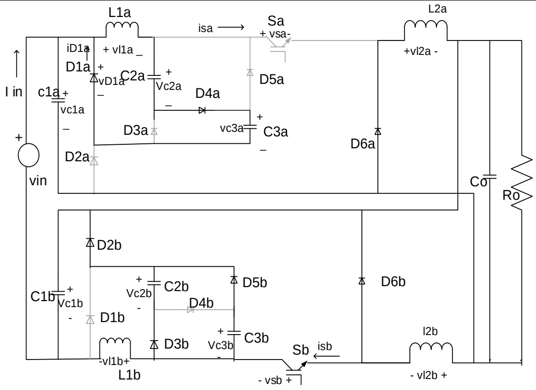


Fig: D. Third mode [32].

2.1. 1[ST]converter:

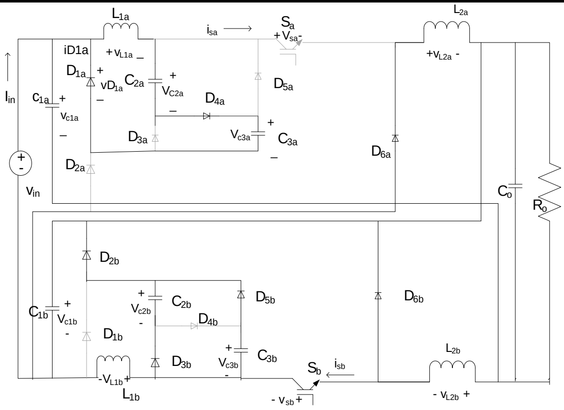


Fig. 2.C. Second mode [32].

The outcome waveforms of suggested converter are exhibited in this converter, where the switches have been interleaved with 180° shift phases. *Mode 1* ($t_o<t<t_1$): In the first switching mode, diodes D_{2a}, D_{3a}, D_{5a}, D_{1b}, $D_{4b}$and D_{6b} and switch S_a *is* 'ON', even, the alternate diodes and switch is 'OFF'. The stage referring the equivalent circuit can be shown in Figure. 1*B*, consequently, the inductor voltages in the first

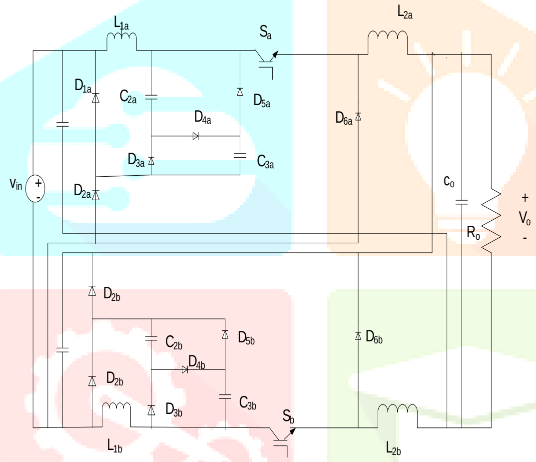


Fig: 2.A. Equivalent circuit of second converter [32]

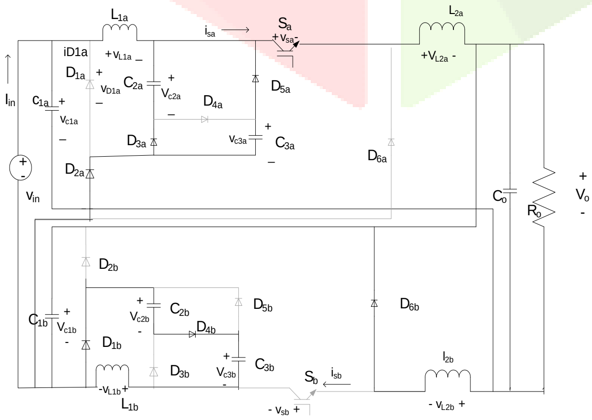


Fig:2.B. First mode [32].

Mode is considered as $v_{L1a}= V_{C1a}- V_{C2a}$and $v_{L2a}= V_{C3a}- V_o$. In addition, the inductor voltages in the second mode are considered as $V_{L1b}= -(V_{C2b} + V_{C3b}) = -2V_{C2b}$and $V_{L2b}= -V_o$. Modes 2 & 4 ($t_1 \leq t < t_2$ & $t_3 \leq t < t_4$): In the 4[th] and 2[nd] switching modes, diodes D_{1a}, D_{4a}, D_{6a}, D_{1b}, D_{4b}, and $D_{6b}$are ON, while alternative diodes and switches are OFF. The circuit equivalence of this mode is shown in Figure, 1C. Accordingly, inductor voltages are considered as $v_{L1a}= -(V_{C3a}+ V_{C2a}) = -2V_{C2a}$, $V_{L2a}= -V_o$, $V_{L1b}= -2V_{C2b}$, and $V_{L2b}= -V_o$. Mode 3 ($t_2<t<t_3$): In the 3[rd] switching mode, switch S_b and diodes D_{1a}, D_{4a}, D_{6a}, D_{2b}, D_{3b}, $D_{5b}$are 'ON'. While the other diodes and switches are 'OFF'. The circuit equivalence of this mode is shown in Figure. 1*D*. so, the inductor voltages can be considered as $V_{L1a}= -2V_{C2a}$, $V_{L2a}= -V_o$, $V_{L1b}= V_{C1b}- V_{C2b}$, and $V_{L2b}= V_{C3b}- V_o$. The proposed controller has been shown in Figure 3.

III. Steady State Analysis

III.A. Voltage Gain

The inductor voltage will be equivalent to 0(Zero) at the consistent state mode at the standpoint of the law of voltage balance for inductors. So, while incorporating the voltage balance law for inductors L_{1a}, L_{2a}, L_{1b}, and L_{2b} outcomes in the following equations:

$$V_{L1A}= (DV_{C1a} - V_{C2a}) + (1 - D)(-2V_{C2a}) = 0 \quad (a)$$

$$V_{L2A}= V(V_{C3a} - V_o) + (1 - D)(-V_o) = 0 \quad (b)$$

$$V_{L1B}= V(V_{C1b} - V_{C2b}) + (1 - D)(-2D_{C2b}) = 0 \quad (c)$$

$$V_{L2B}=D(V_{C3b} - V_o) + (1 - D)(-V_o) = 0 \quad (d)$$

Obtained equations from figure 1A

$$V_{C1a} - V_{C1b} = V_0 + V_i \quad (e)$$

$$V_{C1a}=V_{C1b}=\frac{(2-D)V_0}{D^2}=\frac{(2-D)V_i}{D^2[(2(2-D)/D^2)-1]} \quad (f)$$

$$V_{C3a}=V_{C2a}=V_{C3b}=V_{C2b}=\frac{V_0}{D}=\frac{V_i}{D[(2(2-D)/D^2)-1]} \quad (g)$$

$$G\frac{V_0}{V_i}=\frac{1}{[(2(2-D)/D^2)-1]}=\frac{D^2}{4-2D-D^2} \quad (h)$$

III.B. Voltage stress on diodes and switches

As shown in Figures. 1*B*–*D*, the voltage stress across diodes as well as switches at the time of their respective intervals can be attained as stated below. The calculated voltage stresses as shown below are applied to the diodes and switches at the interval time of $[1-D]T_s$:

$$V_{sa}=V_{sb}=V_{c1a}+V_{c2a}+V_{c3a}=\frac{(2+D)V_0}{D^2}=\frac{(2+D)V_i}{2(2-D)-D^2} \quad (i)$$

$$V_{D2a} = V_{D2b} = V_{c1a} = \frac{(2-D)V_i}{2(2-D)-D^2} \qquad \text{(j)}$$

$$V_{D3a} = V_{D5a} = V_{D3b} = V_{D5b} = V_{C3a} = \frac{Dv_i}{2(2-D)-D^2} \qquad \text{(k)}$$

$$V_{D4a} = V_{D6a} = V_{D4b} = V_{D6b} = V_{C3a} = \frac{Dv_i}{2(2-D)-D^2} \qquad \text{(l)}$$

2.3.2nd converter:

The proposed circuit of 2nd converter is shown in Figure. 2A. the current and voltage waveforms of this converter are shown in Figure. In this converter, switch Sa is 'ON 'once the switch S_b is 'OFF'. Along these lines, the pre-owned witching example is so straightforward. The converter is having two switching modes that are clarified in the accompanying. Mode 1 (t0< t < t1):In the 1st switching mode, switch Sa, diodes D2a, D3a, D5a, D1b, D4band D6bare ON, On the other hand the other switch and diodes have gone OFF. The equivalent circuit of this mode is shown in Figure. 2B. so, the inductor voltages in the 1ststage are considered as VL1a= Vi − VC2a, VL2a= VC3a− VC1b. In order, to calculated the inductor voltages in the 2nd stage is VL1b= − (VC2b+ VC3b) = − 2VC2b and V2b= − Vo. Mode 2 [t1 ≤ t <t2]: In the 2nd switching mode, switch Sb and diodes D1a, D4a, D6a, D2b, D3b, and D5bare ON, on the other hand other switch and diodes are OFF. The equivalent circuit of this mode is shown in Figure. 2C. Therefore, the inductor voltages are considered as VL1a= − 2VC2a, VL2a= − VC1b, VL1b= VC1b− VC2b, and VL2b= VC3b− Vo. Consequently, the Direct Current characteristics of the 2ndproposed converter consisting of the voltage throughout the capacitors, voltage gain, voltage stress on diodes and switches, average currents of switches, inductors, and diodes suitable inductances values (L1a, L2a, L1b, L2b) to accomplish CCM operation &components number (NComponent) are summarized. The proposed controller has been shown in Figure 3.

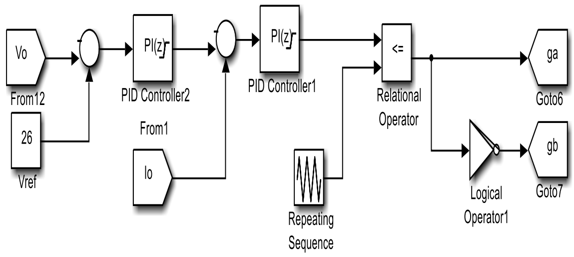


Fig 3: Proposed controllers in the system

From fig 4.The buck converter is used to reduce the amplitude of the output voltage when compared to input voltage. The output ripples can be minimized because of the presence of filter in the output side. The function of pi controller is to reduce the steady state error and to regulate the output voltage at all time irrespective of the load condition and input voltage variations.

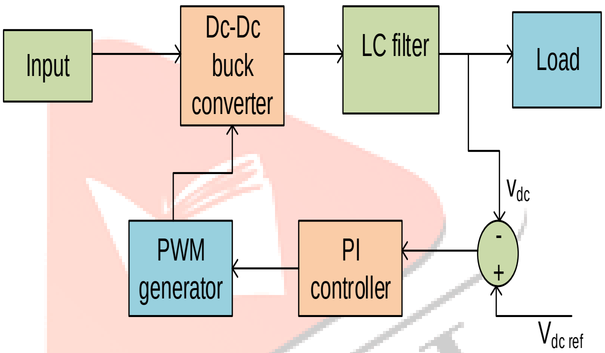


Fig4: Block diagram of buck converter with closed loop system.

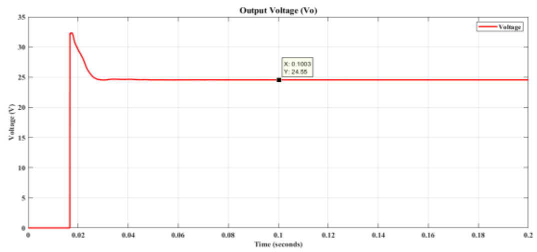
IV Performance Comparison

DC-DC Converters	$\frac{V_o}{V_i}$	$\frac{V_s}{V_i}$	$\frac{V_s}{\sum V_i}$	$\frac{V_D}{V_i}$	$\frac{V_D}{\sum V_i}$	Ncomponents
Converter-1	$\frac{\dot{D}^2}{4-2\dot{D}-\dot{D}^2}$ FOR D< 0.5	$\frac{D+2}{2(2-\dot{D})-\dot{D}^2}$ S_a, S_b:	$\frac{\dot{D}+2}{2(2-\dot{D})-\dot{D}^2}$	$D_{1a}, D_{1b}\, D_{2a}\, D_{2b}$ $\frac{2+\dot{D}}{2(2-\dot{D})-\dot{D}^2}$ $D_{3b}, D_{4b}\, D_{5b}\, D_{6b}$ $\frac{\dot{D}}{2(2-\dot{D})-\dot{D}^2}$	$\frac{8}{2(2-\dot{D})-\dot{D}^2}$	25
Converter-2	$\frac{\dot{D}^2(1-\dot{D})^2}{(1-\dot{D})(2-\dot{D})}$	S_a: $\frac{2+\dot{D}}{2-\dot{D}}$ S_b: $\frac{(3-\dot{D})\dot{D}^2}{(1-\dot{D})(2-\dot{D})}$	$\frac{2+3\dot{D}+4\dot{D}^2-\dot{D}^3}{(2-\dot{D})(1+\dot{D})}$	$D_{3a}, D_{4a}, D_{5a}, D_{6a}$: $\frac{\dot{D}}{(2-\dot{D})}$ $D_{3b}, D_{4b}, D_{5b}, D_{6b}$, $\frac{(1-\dot{D})}{(1+\dot{D})}\frac{\dot{D}^2}{(2-D)}$	$\frac{4+6D+8D^2-2D^3}{(1-\dot{D})(2-\dot{D})}$	25

3.0 Results and Discussion:

For the 1st converter by applying interleaved pulse width modulation with 180 degree phase shift, we got the output voltage is 25.59v (theoretical), 26v (practical) values.

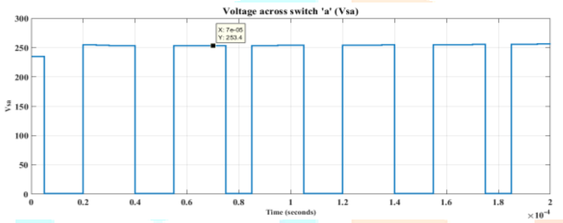
This system can be operated in closed loop due to adding LC filter in output side



(a)Output voltage

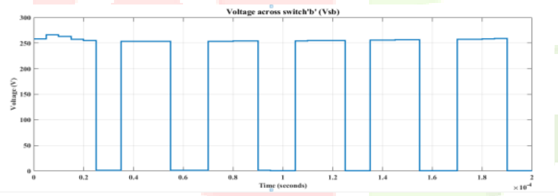
V_{sa}-V_{sb}:

The voltages across switch sa is 253.4v from practical value of the 1stconverter.



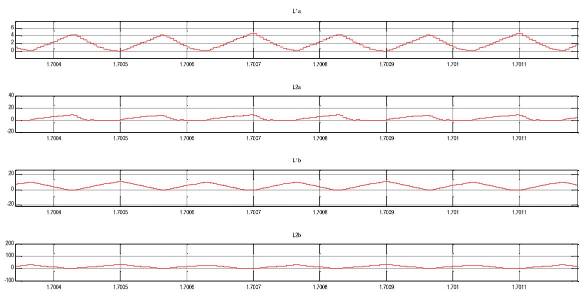
(b)V_{sa}

The voltage across switch sb is 250v from practical value of the2nd converter.



V_{sb}

The inductor currents of converter 2.

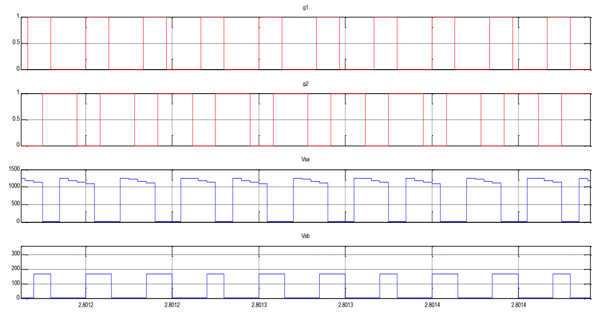


Time(s)

(d) i_a

The pulses and voltages across switches sa and sb of the converter 2.

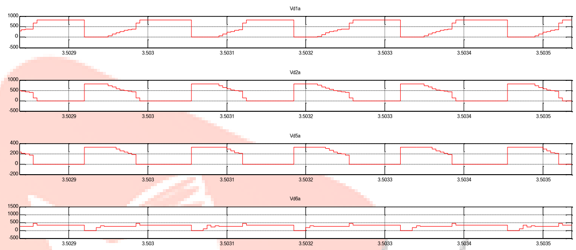
The voltage across switch sa is 1200v and sb is 190v from the practical values.



Time(s)

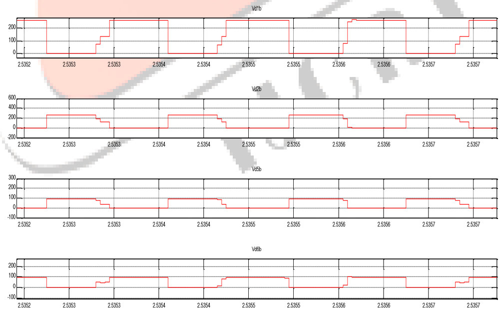
(e) pulse

The voltages across diodes of 2nd converter. The practical values are obtained from MATLAB/Simulink are shown in below figure.



Time(S)

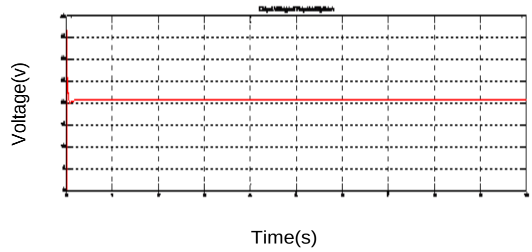
(f) Voltages Vd1-Vd4



Time(s)

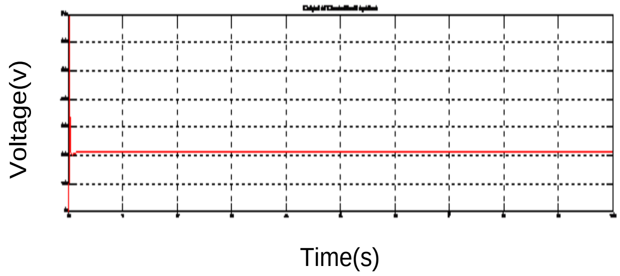
(g) Voltages from (Vd1b-Vd4b)

The output voltage of 2nd proposed converter is 20.4v



(e) V_o of proposed system

The output voltage of 2nd kconventional converter is 20.49v.



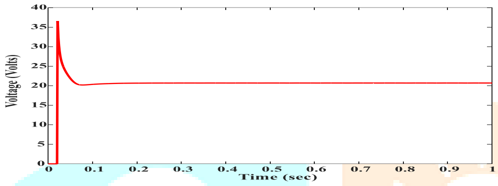


Fig: Converter 2.output voltage

(f)V_o of conventional system

	Magnitude (over shoot)	Settling time
Conventional	90	0.05
proposed	29	0.01

V. Experimental results:

parameters	values
Input voltage	V_{in} =500 for first converter1 V_{in} =800 for first converter2
Duty cycle	D=0.4
Frequency of switches	F_s=30KHZ
Inductors	L1a=7mH,L2a=500Uh,L1b=1m H, L2b=100uF.
Capacitors	C1a=C1b=C2a=C3a=C2b=C3b=Co=330uF.
Output resister	Ro=1.6Ω converter1 Ro=1.5Ω converter 2

VI. Conclusion

The present work consists two high step-down based DC to DC converter has been suggested in the system with two different switching patterns using LC filter for maintain the scheduled voltage and current. In this study, the transformer and inductors are not presented in the structure of the suggested converter. Moreover, the closed loop structure is proposed in this study with LC filter for mitigating the harmonics and other power quality issues. The suggested LC filter has been designed in the converter's output side for switching patterns. The first designed converter has been operating at the duty cycle ration is less than 0.5 and utilized the conversion converter for conversion. Similarly, the second developed converter is designed with total range of duty cycle with the help of single conversion ratio equation. The 1st converter voltages stresses is less than the 2nd converter. The suggested system has been developed in the MATLAB/Simulink environment. The suggested closed loop network shows superior performance in terms of all operating conditions as compared with other techniques.

REFERECES:

[1] Hwu, K.I., Jiang, W.Z.: 'Non-isolated two-phase interleaved LED driver with capacitive current sharing', IEEE Trans. Power Electron., 2018, 33, (3), pp. 2295–2306

[2] Marvi, F., Adib, E., Farzanehfard, H.: 'Efficient ZVS synchronous buck converter with extended duty cycle and low-current ripple', IEEE Trans. Ind. Electron., 2016, 63, (9), pp. 5403–5409

[3] Ren, R., Liu, B., Jones, E.A., et al.: 'Capacitor-clamped, three-level GaNbased DC–DC converter with dual voltage outputs for battery charger applications', IEEE J. Emerging Sel. Top. Power Electron., 2016, 4, (3), pp. 841–853

[4] Tan, L., Zhu, N., Wu, B.: 'An integrated inductor for eliminating circulating current of parallel three-level DC–DC converter-based EV fast charger', IEEE Trans. Ind. Electron., 2016, 63, (3), pp. 1362–1371

[5] Kanani, N.: 'Electroplating – basic principles, processes and practice' (Elsevier, London, UK, 2006)

[6] Trzynadlowski, A.M.: 'Introduction to modern power electronics' (John Wiley & Sons, Hoboken, NJ, USA, 2016, 3rd edn.)

[7] Amiri, M., Farzanehfard, H., Adib, E.: 'A non-isolated ultra-high step down DC–DC converter with low voltage stress', IEEE Trans. Ind. Electron., 2018, 65, (2), pp. 1273–1280

[8] Hwu, K.I., Jiang, W.Z., Wu, P.Y.: 'An expandable two-phase interleaved ultrahigh step-down converter with automatic current balance', IEEE Trans. Power Electron., 2017, 32, (12), pp. 9223–9237

[9] Modeer, T., Norrga, S., Nee, H.-P.: 'High-voltage tapped-inductor buck converter utilizing an autonomous high-side switch', IEEE Trans. Ind. Electron., 2015, 62, (5), pp. 2868–2878

[10] Yau, Y.-T., Hwu, K.-I., Jiang, W.-Z.: 'Step-down converter with wide voltage conversion ratio', IET Power Electron., 2015, 8, (11), pp. 2136–2144

[11] Jin, K., Gu, L., Cao, W., et al.: 'Nonisolatedflyback switching capacitor voltage regulator', IEEE Trans. Power Electron., 2013, 28, (8), pp. 3714–3722

[12] Hwu, K.-I., Jiang, W.-Z.: 'Voltage gain improvement of a high-step-down converter with coupled-inductor core size reduction based on flux linkage',
IEEE Trans. Power Electron., 2018, 33, (7), pp. 6033–6047

[13] Liu, H., Hu, H., Wu, H., et al.: 'Overview of high-step-up coupled-inductor boost converters', IEEE J. Emerging Sel. Top. Power Electron., 2016, 4, (2), pp. 689–704

[14] Kirshenboim, O., Peretz, M.M.: 'High-efficiency non-isolated converter with very high step-down conversion ratio', IEEE Trans. Power Electron., 2017, 32, (5), pp. 3683–3690

[15] Chen, Y., Zhong, Z., Kang, Y.: 'Design and implementation of a transformerless single-stage single-switch double-buck converter with low DC-link voltage, high step-

down, and constant input power factor features', IEEE Trans. Power Electron., 2014, 29, (12), pp. 6660–6671.
[16] Dusmez, S., Hasanzadeh, A., Khaligh, A.: 'Comparative analysis of bidirectional three-level DC–DC converter for automotive applications', IEEE Trans. Ind. Electron., 2015, 62, (5), pp. 3305–3315
[17] Axelrod, B., Berkovich, Y., Ioinovici, A.: 'Switched-capacitor/switchedinductor structures for getting transformerless hybrid DC–DC PWM converters', IEEE Trans. Circuits Syst. I, Regul. Pap., 2008, 55, (2), pp. 687– 696
[18] Babaei, E., Saadatizadeh, Z.: 'A new interleaved bidirectional dc/dc converter with zero voltage switching and high voltage gain: analyses, design and simulation', Int. J. Circuit Theory Appl., 2017, 45, (11), pp. 1773–1800
[19] Saadatizadeh, Z., ChavoshipourHeris, P., Sabahi, M., et al.: 'A new nonisolated free ripple input current bidirectional DC-DC converter with capability of zero voltage switching', Int. J. Circuit Theory Appl., 2018, 46, (3), pp. 519–542
[20] Babaei, E., Saadatizadeh, Z., Cecati, C.: 'High step-up high step-down bidirectional DC/DC converter', IET Power Electron., 2017, 10, (12), pp.
1556–1571
[21] Babaei, E., Saadatizadeh, Z.: 'High voltage gain dc–dc converters based on coupled inductors', IET Power Electron., 2018, 11, (3), pp. 434–452
[22] Vázquez, N., Reyes-Malanche, J.A., Vázquez, E., et al.: 'Delayed quadratic buck converter', IET Power Electron., 2016, 9, (13), pp. 2534–2542
[23] Reyes-Malanche, J.A., Vázquez, N., Leyva-Ramos, J.: 'Switched-capacitor quadratic buck converter for wider conversion ratios', IET Power Electron., 2015, 8, (12), pp. 2370–2376
[24] Veerachary, M.: 'Two-switch semiquadratic buck converter', IEEE Trans. Ind. Electron., 2017, 64, (2), pp. 1185–1194
[25] Ilic, M., Maksimovic, D.: 'Interleaved zero-current-transition buck converter', IEEE Trans. Ind. Appl., 2007, 43, (6), pp. 1619–1627
[26] Lee, I.-O., Cho, S.-Y., Moon, G.-W.: 'Interleaved buck converter having low switching losses and improved step-down conversion ratio', IEEE Trans. Power Electron., 2012, 27, (8), pp. 3664–3675
[27] Ching-Tsai, P., Chen-Feng, C., Chia-Chi, C.: 'A novel transfromerless interleaved high step-down conversion ratio DC–DC converter with low switch voltage stress', IEEE Trans. Ind. Electron., 2014, 61, (10), pp. 5290–5299
[28] Esteki, M., Poorali, B., Adib, E., et al.: 'Interleaved buck converter with continuous input current, extremely low output current ripple, low switching losses, and improved step-down conversion ratio', IEEE Trans. Ind. Electron.,2015, 62, (8), pp. 4769–4776
[29] Esteki, M., Adib, E., Poorali, B., et al.: 'High step-down interleaved buck converter with low voltage stress', IET Power Electron., 2015, 8, (12), pp.
2352–2360
[30] Hwu, K.I., Jiang, W.Z., Wu, P.Y.: 'An expandable four-phase interleaved high step-down converter with low switch voltage stress and automatic uniform current sharing', IEEE Trans. Ind. Electron., 2016, 63, (10), pp. 6064–6072
[31] Chuang, C.-F., Pan, C.-T., Cheng, H.-C.: 'A novel transformer-less interleaved four-phase step-down DC converter with low switch voltage stressand automatic uniform current-sharing characteristics', IEEE Trans. Power Electron., 2016, 31, (1), pp. 406–417
[32]Zahra saadatizadeh1,Pedram Chavoshipour Heris1, Mehran Sabahi1, Ebrahim Babaei1, 2.: 'Two new transfromerless high step-down dc-dc converters', IET Power Electron., 2019, 12,(5), pp. 1205-1219
[33] K. Pooja, Ch. Krishna Rao& K. B. MadhuSahu "Power Quality Improvement in STATCOM Based PQ-controller For Grid connected to Wind Energy System"Journal of Emerging Technologies and Innovative Research (JETIR) ,ISSN: 2349-5162; November 2018, Volume 5, Issue 11.
[34] A. BhaskaraRao, Ch. Krishna Rao , K. B. MadhuSahu& K. B. Saikiran "A Fuzzy Based Dvr For Mitigation Of VoltageSag/Swell Problems"Journal of Advanced Research in Dynamical and Control Systems (JARDCS) ISSN: 1943-023X; Vol. 6, Issue 14, 2017, ,pp.568-580.
[35] G.Bharat Reddy, Ch. Krishna Rao , K. B. MadhuSahu& K. B. Saikiran "A Fuzzy based MC-DPFC for Enhancement of Power Quality in Transmission Line " International Journal of Pure and Applied Mathematics, ISSN: 1311-8080 (printed version); ISSN: 1314-3395 (on-line version); Volume 117 No. 21 2017, 231-241.
[36] B. Santhosh Kumar, Ch. Krishna Rao , K. B. MadhuSahu& K. B. Saikiran "Enhancement Of Power Quality Using Fuzzy Controlled D-Statcom In Distribution System" International Journal of Electrical and Electronics Engineering Research (IJEEER)ISSN(P): 2250-155X; ISSN(E): 2278-943X Vol. 7, Issue 3, Jun 2017, 1-12© TJPRC Pvt. Ltd.
[37] D. Rama chadraRao, Ch. Krishna Rao , K. B. MadhuSahu& K. B. Saikiran "Enhancement Of Power Quality Using Mc-Dpfc In Transmission System" International Journal of Electrical and Electronics Engineering Research (IJEEER) ISSN(P): 2250-155X; ISSN(E): 2278-943X Vol. 6, Issue 6, Dec 2016, 1-12 © TJPRC Pvt. Ltd.
[38] B.Divya, Ch. Krishna Rao& K. B. MadhuSahu "Three Phase Grid Connected Transformer less Inverter for Photovoltaic with PMSM drive" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, Number 3(2016) pp. 2042-2048 © Research India Publications.
[39] P.PhalgunaRao, K. B. MadhuSahu& Ch. Krishna Rao "Performance Evaluation of High Step-Up DC-DC Converter Working Under Closed Loop Control Scheme" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 15 (2015) pp. 35153-35159 © Research India Publications.
[40] P.TulasiRao , CH.KrishnaRao, K.B.MadhuSahu " An Advanced Power electronics Interface For Photovoltaic Powered Induction motor based Electric vehicle" ISSN 0976 – 6545(Print) ISSN 0976 – 6553(Online)Volume 5, Issue 12, December (2014), pp. 310-320.
[41]CH.KrishnaRao, Dr.KBMadhuSahu Dr. Siva Yellampalli,B B Rao, "Performance of a Fuzzy Logic Based AVR in SMIB, MMIB System and Power Flow Control Using SSSC and IPFC," IJERA, Vol. 2, IssueNo. 1, pp. 260-268.
[42]CH Krishna Rao, K.B.Madhu Sahu, I Ramesh, A.Jagannadham"Application of SSSC and IPFC for Stability Enhancement for SMIB and MMIB using FUZZY Logic Controller" ISSN: 2321 – 919X, Vol 2, Issue 4 ,April, 2014