AN INTERLINKED BU-BO DEVICE FOR MORE VOLTAGE LEVELS

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Abstract- A novel transformer-less Bu-Bo device with general topology is displayed in this study. Compared with the conventional Bu-Bo device, the displayed Bu-Bo device's voltage rise is squared times of the former's and its o/p voltage polarity is +ve. These advantages enable it to work in a large area of +ve o/p. The 2 energy switches of the displayed Bu-Bo device work together. In the continuous conduction mode (CCM), 2 inductors are charged and 2 capacitors are drained all along the switch-on time, while 2 inductors are discharged and 2 capacitors are filled all along the switch-off time. The operating principles, the steady-state studys, and the less-signal model for the displayed Bu-Bo device operating in CCM are displayed in detail. The PSIM simulations and the schematic experiments are taken to validate the effectiveness of the displayed Bu-Bodevice.

I. INTRODUCTION

As is well known, commutation-mode energy supply is the main of modern energy transformation technology, which is widely taken in electric energy, communication system, domestic devices, industrial device, and different areas [1] [2]. As the basis of commutation-mode energy supply, device topologies draw a better deal of attention and many device topologies have been displayed. Buck device and boost device have the general schematic and more performance.

Then also, due to the restricted voltage rise, their usages are restricted when the less or more o/p voltage are required [3]. Luo devices can generate more voltage rise by using the voltage boost technique, but the topological hardness, price, volume, and losses rise at the same time [4]–[6]. Interlinked devices can get more boost or buck transformation ratio with less-voltage stress, while their operating mode, device schematic, and control principle are hard [7]–[10]. Quadrate devices can get the voltage rise of series devices with lesser switches; then also, the performance of these devices is less. Additionally, some switched networks are added into the basic devices to generate the more-voltage boost or buck rise, at the price of hard design and increasing price [13]–[23]. Compared with the above-given device topologies which can only boost or buck voltage, the voltage bucking/boosting devices, which can control o/p voltage under large area of i/p voltage or load variations, are popular with the usages like as portable electronic devices, car electronic devices, and soon.

The conventional buck–boost device with general schematic and more performance, as we all known, has the setbacks like as restricted voltage rise, -ve o/p voltage, and floating energy switch, all along discontinuous i/p and o/p currents. The other three basic non-isolated devices: 1) Cuk device; 2) Sepic device; and 3) Zeta device,which also have the similarity of boost and buck voltage, have been taken. Then also, the limits of the voltage rise along with other limitations in Cuk, Sepic, and Zeta devices are also non-negligible. The quadrate buck–boost device, displayed by Maksimovic and Cukin [24], has one mutual-earth energy switch; all along, it can get the voltage rise $D^2/(1 - D)^2$. Then also, due to the diodes D_1 and D_2 link the o/p voltage to the i/p voltage while the timing loop is bigger than 0.5, so that this device can only work in buck mode. By combining KY device and the conventional together rectified buck device, Hwu and Peng displayed a new buck–boost device [25] which can realize the continuous o/p current, +ve o/p voltage, continuous conduction mode (CCM) operation all the time, and no right-half plane zero. Unfortunately, its voltage rise of 2 multiplies the timing loop (2D) is not enoughly more or less in the situation where the device needs to work in a wide area of o/p voltage. Moreover, based on the Cuk device, a new buck–boost device, which has the less o/p voltage ripple, minimal radio frequency interference, and one mutual-earth energy switch, is displayed [26]. Then also, as a seventh-order schematic, the device has complex design, and both its i/p terminal and o/p terminal do not share the same earth. Apart from that, the voltage riseis still restricted. In [27] a boost–buck series device, aggregating 2 divided devices with current supply and current sink is applied for the thermoelectric generator. Nevertheless, the voltage rise of this series device is also constrained.

Especially, in order to generate more-voltage boost or buck rise, these devices must beoperating under highly more or less timing loop, and this point is too hard to realize due to the practical constraints. Hence, exploring new topology of buck–boost device to overcome the setbacks of the conventional ones for satisfying the increasingly requirements in industrial usages is very important and valuable. In this study, by inserting an additional switched ne2rk into the conventional buck–boost device, a new transformer-less buck–boost device is displayed. The main merit of the displayed buck–boost device is that its voltage rise is quadrate of the conventional buck–boost device, so that it can work in a wide area of o/p voltage, i.e., the displayed buck– boost device can get more or less voltage rise without high timing loop. Moreover, the o/p voltage of this new transformer-less buck–boost device is mutual- earth with the i/p voltage, and its polarity is +ve.

II. PROPOSED DEVICE SCHEMATIC & OPERATION

Fig.1 shows the schematic configuration of the new transformer less buck–boost device, which having of 2 energy switches (S1 and S2), 2 diodes (D1 and D0), 2 inductors (L1 and L2), 2 capacitors (C1 and C0), and one resistive load R. Energy switches S1 and S2 are operated together.

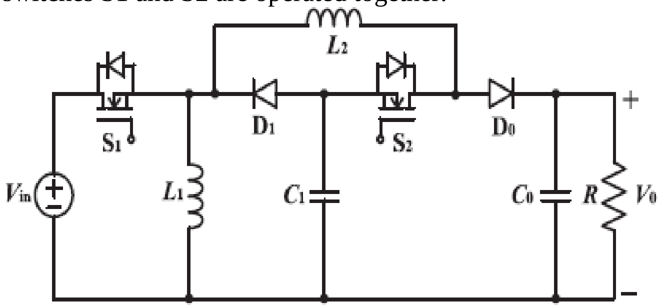

Fig.1: Proposed transformer-less buck–boost device

Based on the mode of the energy switches and diodes, some typical time-domain graphs for this new transformer less buck–boost device operating in CCM are displayed in Fig.2.2 and the possible operation phases for the displayed buck–boost device are mentioned in Fig.3.For Fig.2.3 (a), it denotes that the energy switches S1 and S2 are turned on, whereas the diodes D1 and D0 do not conduct. Consequently, both the inductor L1 and the inductor L2 are charged, and both the charge boost capacitor C1 and the o/p capacitor C0 are is filled. For Fig.2.3(b), it describes that the energy switches S1 and S2 are turned off while the diodes D1 and D0 conduct for its forward biased voltage Hence, both the inductor L1 and the inductor L2 are decharged, and both the charge boost capacitor C1 and the o/p capacitor C0 are filled. Here, in order to simplify the schematic studys and deduction, we assumed that the device works in steady state, all elements are ideal, and all capacitors are large enough to keep the voltage around them constant.

III. OPERATING PRINCIPLES

There are 2 phases, i.e., phase 1 and phase 2, in the new transformer less buck–boost device when it works in CCM operation

Phase 1 (NT < t < (N + D)T):

All along this time interval, the switches S_1 and S_2 are turned on, while D_1 and D_0 are reverse biased. From Fig.3 (a), it is observed that L1 is charged from the i/p voltage Vin while L_2 is charged from the i/p voltage Vin and the charge boost capacitor C_1. Moreover, the o/p energy is given from the o/p capacitor C_0. Thus, the corresponding equations can be established as

$$V_{L1}=V_{in} \quad (1)$$

$$V_{L2} = V_{in} + V_{C1} \quad (2)$$

Phase 2 ((N + D) T<t< (N + 1)T):

All along this time interval, the switches S_1 and S_2 are turned off, while D_1 and D_0 are forward biased. From Fig. 5.3(b), it is observed that the energy storedin the inductor L_1 is released to the charge boost capacitor C_1 via the diode D_1. At the same time, the energy stored in the inductor L_2 is released to the charge boost capacitor C_1, the o/p capacitor C_0, and the resistive load R via the diodes D_0 and D_1. The equations of the state 2 are described as mentioned:

$$V_{L1} = -V_{C1} \quad (3)$$

$$V_{L2} = -(V_{C1} + V_0) \quad (4)$$

If applying the voltage-second balance principle on the inductor L_1, then the voltage around the charge boost capacitor C_1 is readily generated from (1) and (3) as

$$V_{C1} = (D/1–D)V_{in} \quad (5)$$

Here, D is the timing loop, which represents the proportion of the energy switches turn-on time to the total commutation cycle. Similarly, by using the voltage-second balance principle on the inductor L_2, the voltage rise of the displayed buck–boost device can be generated from (2), (4), and (5) as

$$M = V_0/V_{in} = (D/1–D)^2 \quad (6)$$

From (6), it is apparent that the displayed buck–boost device can boost the i/p voltage when the timing loop is bigger than 0.5, and buck the i/p voltage when the timing loop is lesser than 0.5.

IV. INTERLINKED SHUNT DC/DC DEVICE

More boost ratio can get by combining classical boost device with switched inductors, coupled inductors, more frequency transformer or switched capacitor (SC). They can generate more boost ratio with more performance, less voltage stress, and less EMI. In order to decline o/p fuel cell array o/p current harmonic or the DC/DC device i/p current ripple, either a passive filter or active filter can be taken, Then also, this will rise the hardness of the system. In fact, interconnected the DC/DC device can reduce the i/p current ripple of the DC/DC device. An interlinked boost device with voltage booster was displayed. Its voltage rise was raised up to (M +1) times (M is the number of the voltage booster) of the classical boost device with the same duty-cycle D and lesser voltage stress. Apart from that it has lesser i/p current ripples and o/p voltage ripples in comparison to the classical boost device. The interconnected boost device with voltage boosters is mentioned in Fig. 5.2.1.

The simulation schematic device mentioned in Fig. 5.2.1 can get less voltage stress in the energy devices, which escalates the transformation performance. Then also, this is only true in heavy load while the voltage stress of the energy devices escalates when it works in discontinuous mode (DCM). In this case, more voltage energy devices need to be taken, and therefore its price and energy loss will be raised. These authors displayed a new PWM control method, named as Alternating Phase Shift (APS), to overcome the problem when the device works in lightload.

This study finds a novel PWM scheme for shunt interlinked boost device with voltage booster for FECS by combining APS and conventional interconnected PWM control. The APS control is taken to reduce the voltage stress on switches in light load while the conventional interconnected control is taken to keep better competence in heavy load. The limit condition for changing between APS and conventional interconnected PWM control is taken. Based on the above analysis, a full energy area control combining APS and conventional interconnected control is displayed.

V. SIMULATION RESULTS

Based on the MATLAB/simulink software and Fig. 4.1, the simulation schematic of the novel transformer-less bu–bo device can be designed for the simulations to confirm the analyses in Section III primarily. Note that schematic parameters here are taken as:

Vin=18V,fs=20kHz,D=0.4−0.6,L1=1mH,L2=3mH C1=10μF,C0=20μF, R = 30−150 Ω. Fig. 5 shows the time-domain graphs of the o/p voltage v0, the charge boost capacitor voltage vC1, the currents of the 2 inductors L1 and L2, and the driving signal vg for the new transformer-less buck–boost device operating in boost mode when the timing loop is 0.6. Since the 2 energy switches conduct together, only one switching signal vg is chose.

STEP DOWN MODE:

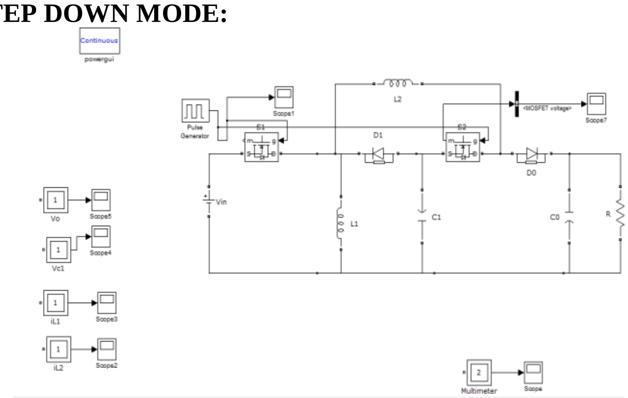

Fig.2: Simulink model of step down mode

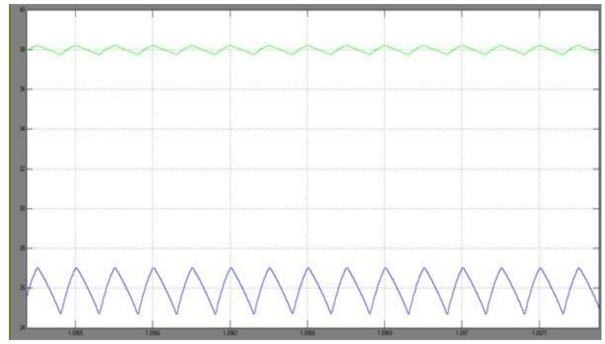

Fig.3: Capacitor (C1) and load resistances voltage wave forms of step down mode

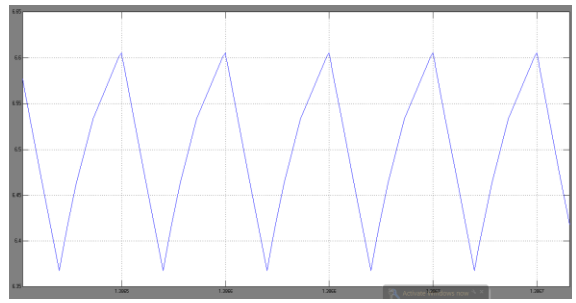

Fig.4: Voltage o/p at load in step down mode

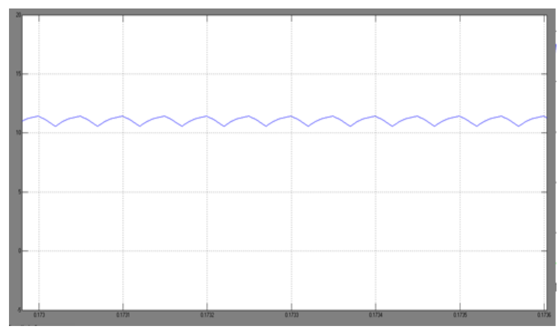

Fig.5: Capacitor around the voltage

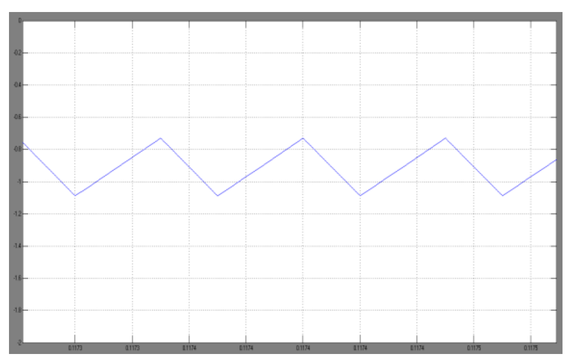

Fig.6: Current around IL1

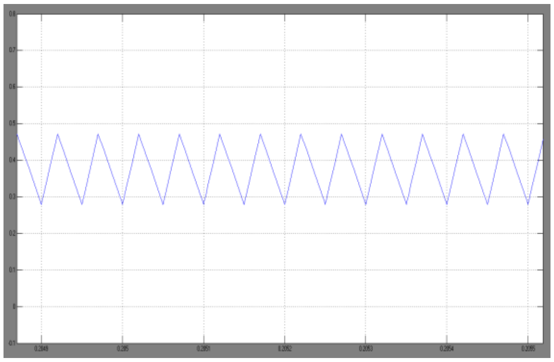

Fig.7: Current around IL2

STEP UP MODE:

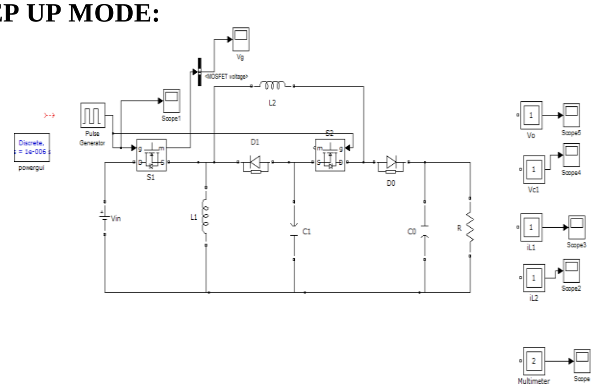

Fig.8: Simulink model of step up mode

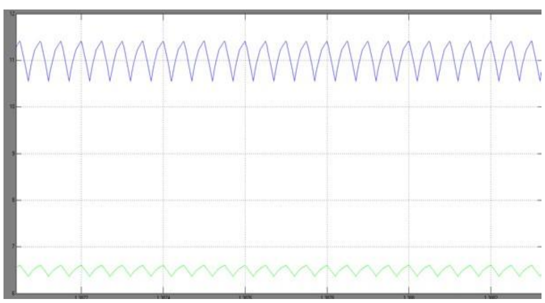

Fig.9: Capacitor (C1) and load resistances voltage graph of step up mode

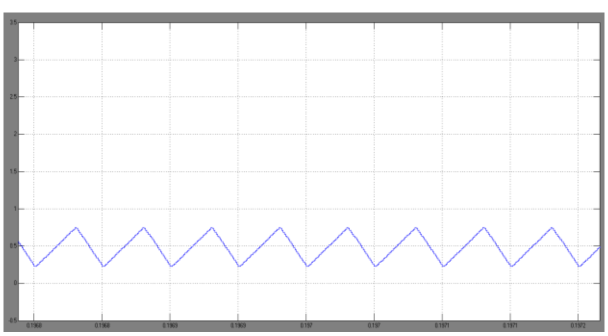

Fig.10: Current around the IL1

VI. SIMULATION RESULTS FOR INTERLINKED SHUNT DC\DC DEVICE

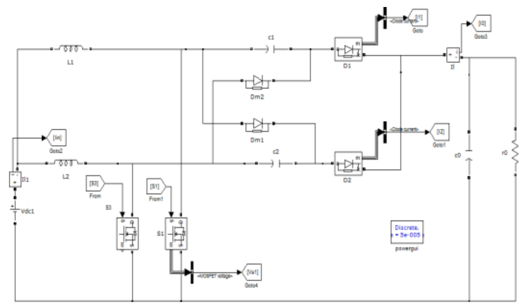

Fig.11: Fuel cell more boost DC/DC device

The schematic parameters are as given, Vin =100 V, VO=700 V, C1=C2=40 μF, CO= 195 μF, L1=L2=1158 μH, TS=100 μs. The load at boundary condition is RBC=2032 and Kcrit=0.011 at boundary condition, the timing loop Dm at limit condition is 0.44

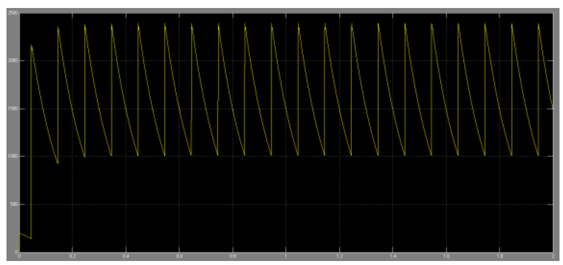

Fig.12:Voltage around the Load resistance

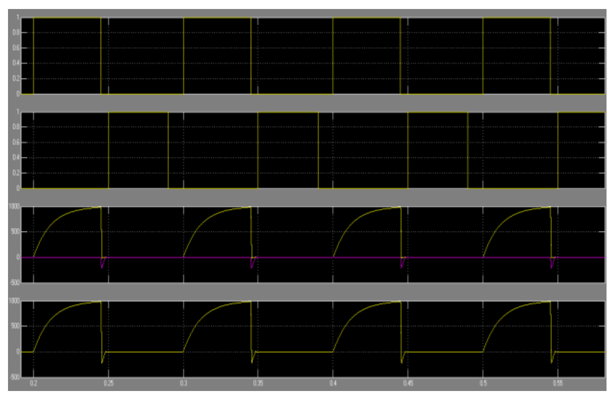

Fig.13 Commutation signals, i/p inductor currents and i/p fuel cell current

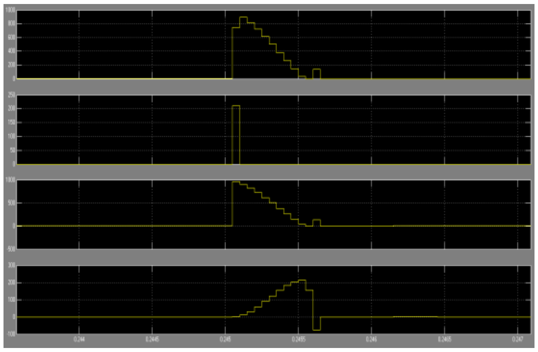

Fig.14 Diodes currents (D1, D2), o/p current and capacitor-2 current

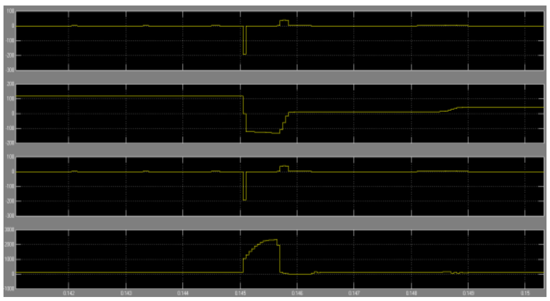

Fig.15 Capacitor-1 current, voltages around the capacitors, switch (S1) voltage

VII. CONCLUSION

This Project has displayed a new transformer less buck–boost device as a fourth-order schematic, which realizes the optimization between the topology design and the voltage rise to overcome the setbacks of the conventional buck–boost device. The operating principles, steady-state studies, less signal modeling, and comparisons with other devices are displayed. From the theoretical studies, the MATLAB simulations, itis proved that the new transformer less buck–boost device possesses the merits like as more boost/buck voltage rise, +ve o/p voltage. Hence, the displayed buck–boost device is suitable for the industrial usages requiring more boost or buck voltage rise.

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