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3x Dc-Dc Converter Application for Plug-In Hybrid Electric Vehicles

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Abstract- Hybrid electric vehicle (HEV) traction drives are supplied by both steam engine and battery with dc-dc converter and inverter, while upgrading power rating of commercial HEV, traditional boost converter leads low efficiency and increase in size . This paper proposes a four level dc-dc converter in order to avoid above obstacle's ,in this converter inductor size is decreased double the traditional boost converter ,when comparing To switched capacitor dc-dc converter ,the 3x dc-dc converter can be operating at three variable input and output ratios due to this lowers the capacitance requirement.
KEYWORDS- DC – DC Power Conversion, Multilevel Converter, Pulse width modulation, Voltage Divider, Voltage multipliers.

I. INTRODUCTION

In Hybrid electric vehicle applications We are using in this 3X dc-dc converter (four level dc-dc converter) .The four level dc – dc converter as three discrete input and output voltage ratios depending on the power requirement We will change the duty cycle . Previously In Hybrid electric vehicle We are using traditional dc – dc converter, an inductor is employed. Besides its large size and heavy weight, the loss inductor limits the operating temperature. All above losses we will reduce the four level dc –dc converter. In this converter all switches ON and OFF Time, Depending on the duty cycle. It is not viable to simply resort to increasing the switching frequency to limit the size, weight, and cost of the converter since the core and copper loss of the inductor will go up as a result of the increased switching frequency and the power rating. Multilevel dc-dc converter topologies have been proposed for many applications.

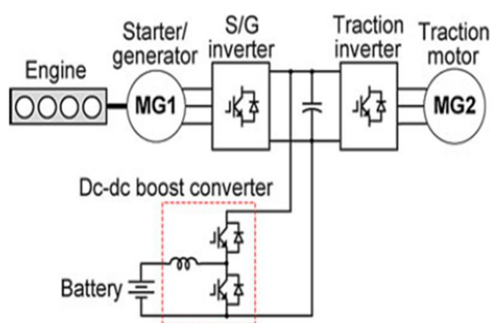

Fig 1: powertrain configuration of conventional series-parallel HEV

Nowadays, the economic and environmental benefits from commercial HEVs have stimulated global interest in further developing plug-in hybrid electric vehicles (PHEVs). For the pure electric drive operation of PHEVs, the dc-dc boost converter has to deliver the full power. Needed by the traction drive, not just the difference between MG1 and MG2 as would be the case in blended operation mode with the engine running (Fig. 1). For example, the present dc-dc converter in the Prius is rated at 20-kW peak power (10-kW continuous power), which is not enough for all-electric operation at higher speeds and has to be upgraded from 20-kW to 55-kW peak power (30-kW continuous) for PHEV's pure electric drive. It is not viable to simply resort to increasing the switching frequency to limit the size, weight, and cost of the converter since the core and copper loss of the inductor will go up as a result of threating. In addition, the semiconductor heat dissipation in the converter limits the switching frequency. In response, multiphase dc-dc converters were developed for high power HEVs and fuel cell vehicles (FCVs). The inductor design is still a challenging issue for increasing the converter efficiency and power density.

II. THREE LEVEL DC/DC CONVERTER FOR DIFFERENT DUTY CYCLES

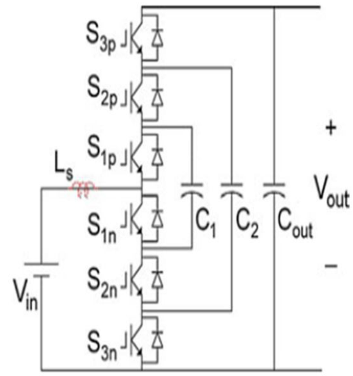

Fig2: THREE LEVEL DC-DC CONVETER

A. *Modes of operation*

when $0 \le D \le ½$, in Fig. 3(a), the operation sequence is Fig. 4(a)-(c)-(b)-(c) otherwise when $1/2 \le D \le 1$, as shown in Fig. 3(b), the sequence is Fig. 4(a)-(d)-(b)-(d).

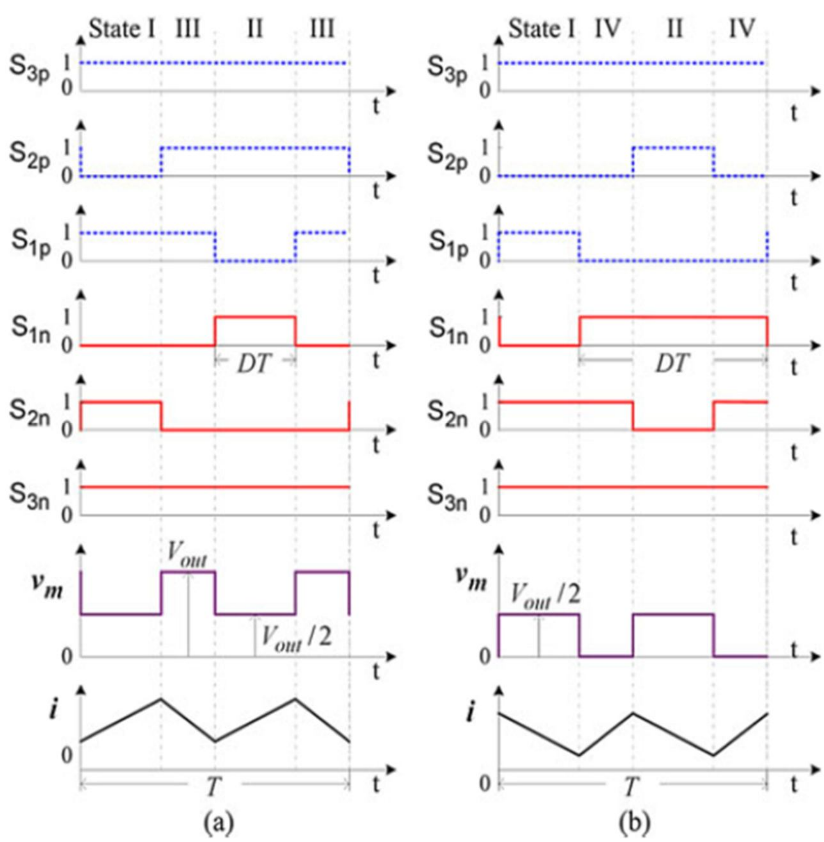

Fig. 3. PWM signals and key waveforms of the three level operation. (a) $0 \le D \le 1/2$. (b) $1/2 \le D \le 1$

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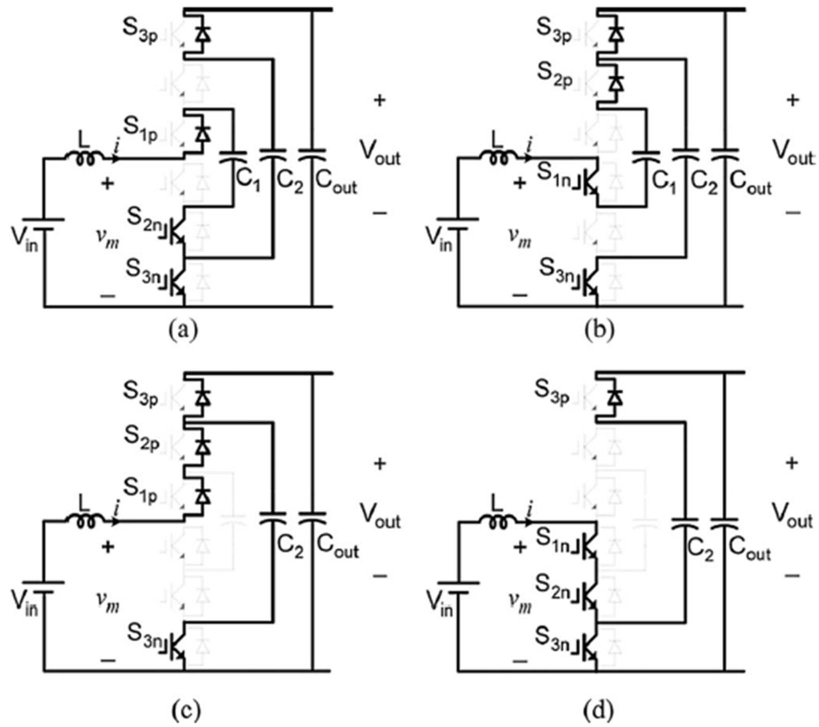
Fig. 4. Switching states of the three-level operation in boost mode. (a) State I. (b) State II. (c) State III. (d) State IV.



III. TRADITIONAL TWO LEVEL DC/DC CONVERTER

One concern about the four-level converter is that six semiconductor switching devices have to be used instead of two in the traditional two-level boost converter. The total switching device power rating (TDPR) or total device power stress (TDPS) of a converter circuit is an indication of how much total silicon area is needed for the semiconductor devices. The following analysis shows that both two- and four-level converters have the same TDPR, thus requiring similar or the same amount of silicon areas. For the six switches in the four-level converter operation, the TDPR is

$$\mathbf{TDPR\text{-}4L=6\ V_{out}/3I_{in}=2m\ P_{out}}$$

where m = Vout/Vin and output power, Pout = Vin Iin = Vout Iout.For the two switches in the traditional two level bidirectional boost converter, the TDPR is

$$\mathbf{TDPR\text{-}2L=2\ V_{out}\ I_{in}=2m\ P_{out}}$$

As can be seen from the above two equations, they have the same total device power rating. For the traditional boost converter, each switch has to sustain the full dc voltage, whereas the switches in the four-level converter only sustain 1/3 of the dc voltage.

IV. PROPOSED FOUR LEVEL DC/DC CONVERTER FOR DIFFERENT DUTY CYCLES

In this section, the general operation and features of the four level flying-capacitor dc-dc converter are explained and discussed first. The relationship between the input current ripple and voltage ratio is derived for the four-level converter and extended to the three- and two-level converters for comparison purposes. The current ripple comparison indicates a dramatic reduction of the inductance requirement. Analysis reveals three operation modes and the relationships between them. In addition, the analytical results will be further used in a later section for transitions from one voltage level to another of the variable 3X operation.

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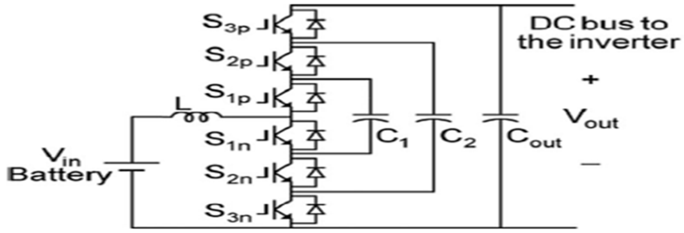

Fig 5 four level flying-capacitor dc-dc converters

A. *Modes of operation for four level inverter*

1) *Mode 1: $0 \le D \le 1/3$:* For $0 \le D \le 1/3$, as can be inferred from Fig. 6(a), the converter operates in a sequence of Fig. 7(a)- (d)-(b)-(d)-(c)-(d) over one switching cycle. The input voltage V_{in} equals the average value of the leg voltage V_m in steady state according to the voltage-second balance of the inductor. The leg voltage V_m is switched between two potentials, $2V_{out}/3$ and V_{out} as shown in Fig. 6(a) For instance, when only S3n is turned ON as shown in the switching state of Fig. 7 (a), C2 gets charged, making Vm = 2Vout /3; when S3n is OFF as shown in Fig. 7(d), the current freewheels through the anti-parallel diodes of S1p, S2p and S3p , making vm = Vout . Similarly for other switching states, when only one of the switches Sjn is ON as shown in Fig. 7(a),(b) and (c), vm = 2Vout /3; otherwise vm = Vout in the freewheeling states in Fig. 7(d). Thus, one can get During this operation range, each inner capacitor, C1 and C2 , gets charged and discharged equally for a duration of DT over one switching cycle as show in Fig.6(a). However, due to gate delays and device tolerance, the voltage of each capacitor, C1 and C2 , may settle down to a value slightly deviated from their theoretical values, V_out/3 and 2V_out /3, respectively.
2) *Mode 2: $1/3 \le D \le 2/3$:* Three new switching states as shown in fig 7(e), (f),and(g) replace the previous freewheeling state. As a result, V_m is switched between two potentials Vout /3 and 2Vout/3 as shown in fig 6(b). the operating sequence follows fig 7(a) – (f) – (b) - (g) – (c) – (e), over one cycle.
3) *Mode 3: $2/3 \le D \le 3$:* In this duty cycle a new state comes into play. All the switches S1n, S2n, and S3n conduct as shown in fig 7(h) consequently Vm presents two voltage levels 0 and Vout/3 as shown in fig 6(c) . the corresponding operating sequence is fig 7(e) – (h) – (f) – (g) – (h) respectfully. In spite of the above three variation Ranges for D, it can expressed in always holds true.

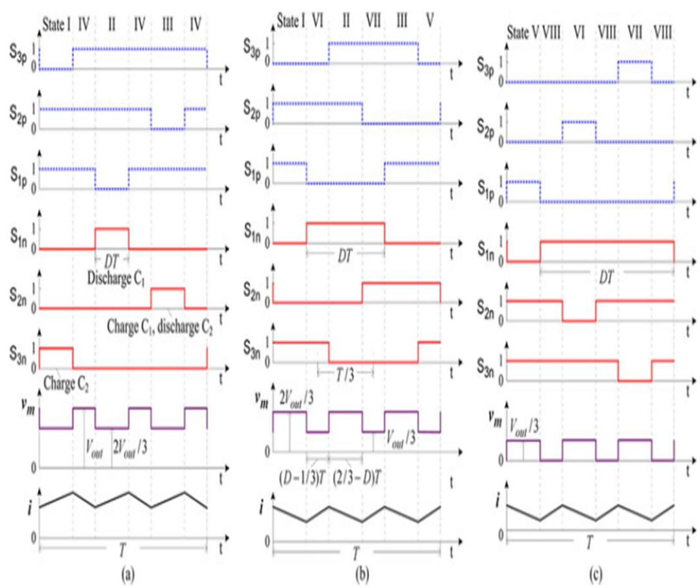

Fig. 7. Switching states of the four-level operation in boost mode. (a) State I. (b) State II. (c) State III. (d) State IV. (e) State V. (f) State VI. (g) State VII. (h) State VIII

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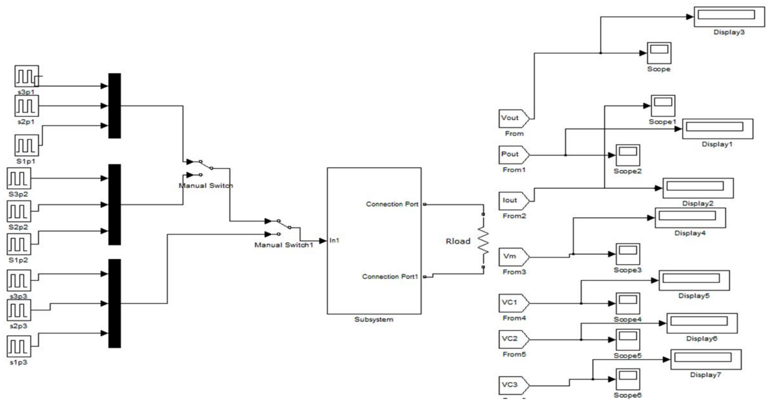
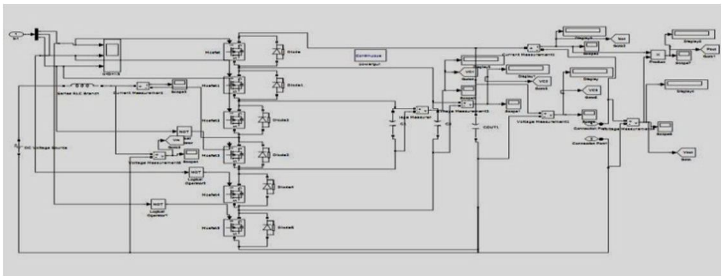
V. SIMULATION RESULTS

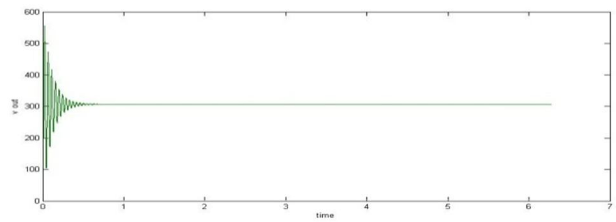
A. Simulation Diagram For 3X DC- DC Converter

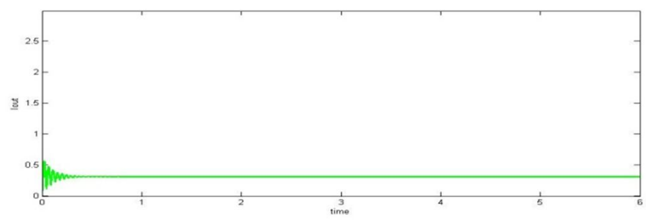


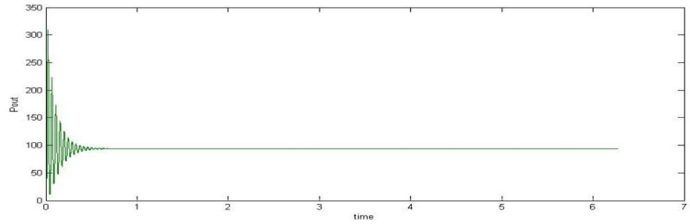


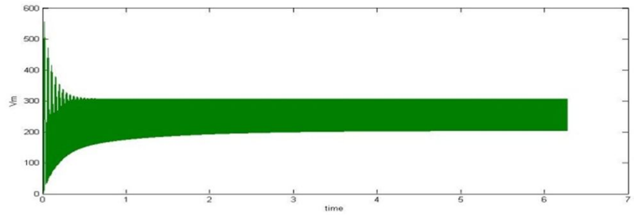
Subsystem

AT DUTY CYCLE 0<D<1/3 FOR V_{out},I_{out} AND P_{out},V_m

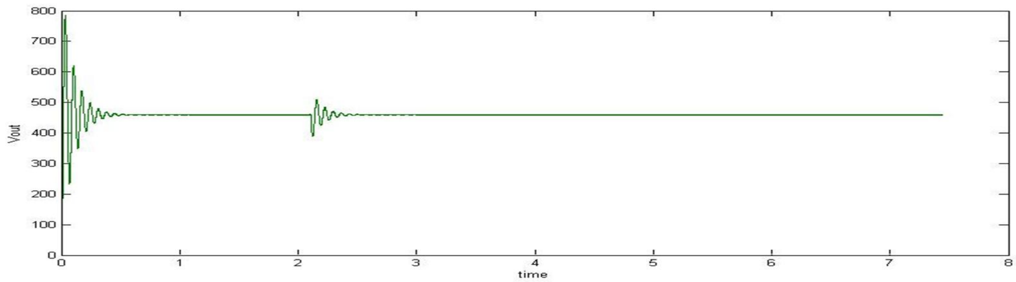


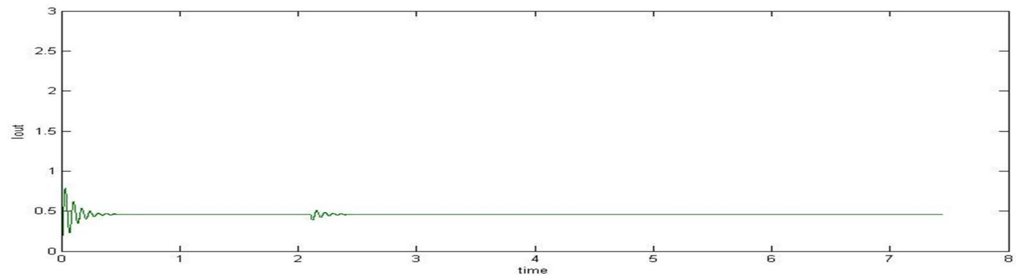


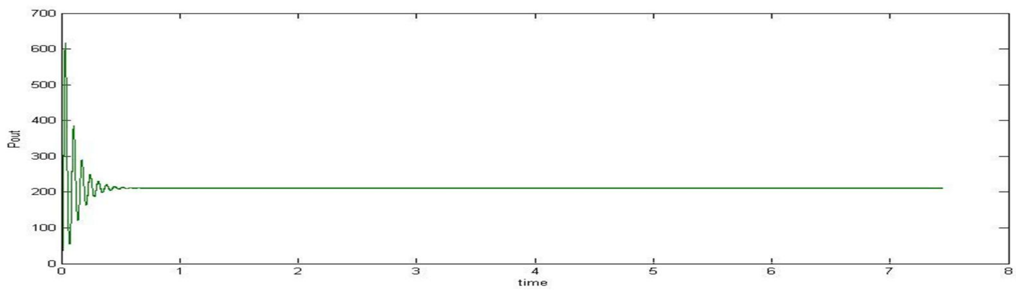


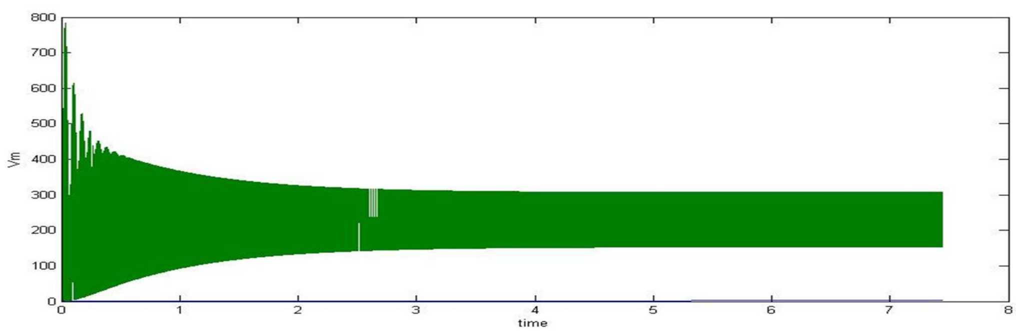


AT DUTY CYCLE 1/3<D<2/3 FOR V_{out},I_{out} AND P_{out},V_m









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AT DUTY CYCLE $2/3<D<3$ FOR V_{out}, I_{out} AND P_{out}, V_m

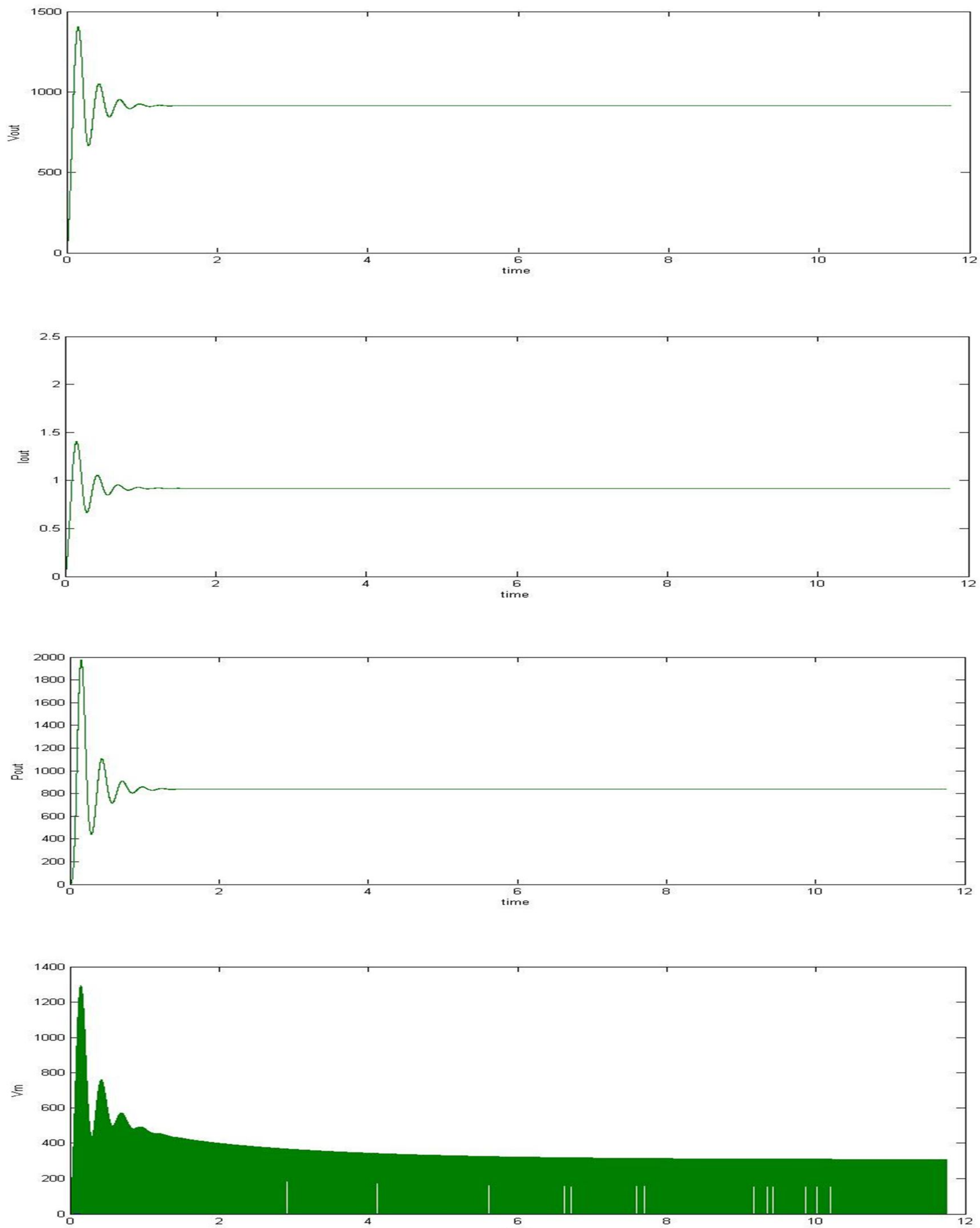
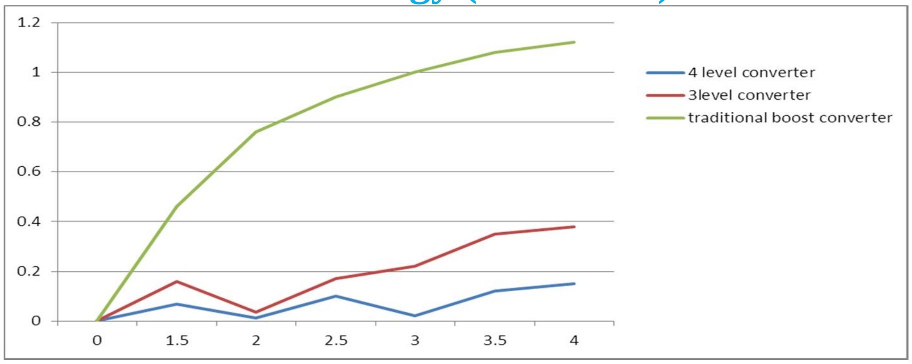


Fig 8 ; Comparison of normalized current ripples



VI. CONCLUSION

In this paper, an alternative solution has been presented to overcome the demerits of the traditional boost converter for application of plug-in HEVs. Analysis has shown that a general four-level flying-capacitor dc-dc converter reduces the inductance requirement dramatically. Moreover, a variable 3X dc-dc converter has been proposed that was derived from the four-level DC-DC converter to further minimize the inductance to null for HEVsand PHEVs that require three discrete voltage levels

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