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Polyphase Boost Converter Integration with Lithium Ion Battery

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***Abstract:** In this paper Lithium-ion battery is most generic sources for electrical automobile. in this action, the lithium-ion battery is integrated with polyphase boost converter and compare with conventional boost converter. This proposed method is tested on software in order to test its efficacy. This comparison is done on the basis of following factors. 1. based on maximum duty ratio. 2. based on size of the inductor.3. based on source ripple current. The result describe the following parameter. The size of inductor reduced to half to that of conventional boost converter and hence the source ripple current lowers significantly.*
***Keywords:** Polyphase Boost Converter, Boost Converter, Lithium-ion Battery*

I. INTRODUCTION

With the Development of lithium-ion battery and polyphase boost converter , there has been increasing interest in various eco-friendly vehicles, like electrical vehicles (EV), plug-in hybrid vehicle which have the potential to reduce the harmful gas like carbon dioxide, sulphur dioxide etc. electrical vehicles can mainly powered by a chargeable battery example of such battery are nickel cadmium, nickel hydroxide ,lead acid (Doerffel and Sharkh 2006), (Nazghelichi, Torabi and Esfahanian, 2018) and lithium-ion batteries (powers, 1995). After the comparative and through studies, it has been concluded that lithium-ion battery are highly reliable, durable, possess high energy densities and small in size as compared to other battery (j.mcdowall, 2000). Because of all these edges, lithium-ion battery is most competent source for electrical vehicle (Aditya and Ferdowsi, 2008). All battery produces DC natured voltage, in order to reduce the capital cost and raise the output voltage it is integrated with dc-dc converter (salimi, 2018). The boost converter as shown in fig1 (a). Was designed by R.midlebrookn has sublime interfacing for dc-dc converter (Middlebrook and Cuk. 1976). The integration of lithium-ion battery has several issues like low frequency ripple current (Is) originating from source generates heating effect in lithium-ion battery (De Breucker et al., 2013). Subsequently it reduces the work life and supply the fluctuating power (Pin) from source as illustrated in fig 1(b).

Another issue in the conventional approach is boost converter has inductor, capacitor and switch as its integral part and higher value of inductor limits the maximum duty operation as well as it causes compatibility issue in the device. These issues can be minimized by using multiphase boost converter (Mallikarjuna Swamy, Guruswamy and Singh, 2014). In this paper the integration (Forsyth and Nuttall, 2006) of lithium-ion battery with multiphase boost converter has been analysed (Garrigos et al., 2018).

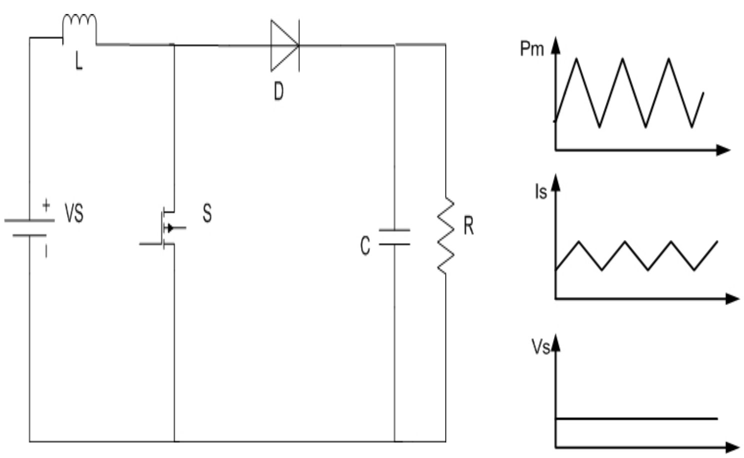

Fig 1(a) Boost converter (b) variation in Pin, Is & Vs

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II. MODELLING OF POLYPHASE BOOST CONVERTER

In polyphase boost converter, additional inductor, diode and switch is required where as number of source and capacitor remain same as conventional boost converter (Thounthong and Davat, 2010) as shown in fig 2. The working of polyphase boost converter depends on number of sequence and duty ratio in this particular case the practice is done on double phase boost converter with duty ratio taken as 0.5 in calculation (Mirzaei and Ramanarayanan 2005).The different parametric comparison of conventional boost converter current with respect to 2-phase boost converter is shown in table-1. In boost converter current (I_L) delivered by inductor (L) is given in table-1 by equation (Eq -2a) is dependent on duty ratio (D) and load current (Io) while in 2-phase boost converter, the current (I_{L1}, I_{L2}) shared by each Inductor (L_1, L_2) is half with respect to conventional boost Converters shown in equation (eq-1a). As the ripple current (ΔI_L, ΔI_{L1}, ΔI_{L2})is also dependent on load current (Io) from equation (eq-1b) and (eq-2b), so it also reduced by half factor shown in Equation (1c) and (2c) if the load current (I_o) remain constant for both cases.

Tab.1a comparison of polyphase boost converter with boost converter.

S.NO	Parameters	2- phase polyphase boost converter	Boost converter	Analysis
1	$I_L = I_{L1} = I_{L2}$	$I_L = I_{L2} = \frac{\left(\frac{I_0}{2}\right)}{1-D}$ Eq-1(a)	$I_L = \frac{I_0}{1-D}$ Eq-2(a)	$I_{L1} = I_{L2} = \frac{I_L}{2}$ Eq-3(a)
2	$\Delta I_L = \Delta I_{L1} = \Delta I_{L2}$	$\Delta I_{L1} = \Delta I_{L2} = 0.4 \times \left(\frac{I_0}{2}\right) \times \frac{V_0}{V_S}$ Eq-1(b)	$\Delta I_L = 0.4 \times \left(\frac{I_0}{2}\right) \times \frac{V_0}{V_S}$ Eq-2(b)	$\Delta I_{L1} = \Delta I_{L2} = \frac{\Delta I_L}{2}$ Eq-3(b)
3	$L - L_1 - L_2$	$L_1 = L_2 = \frac{V_S \times (V_0 - V_S)}{f_S \times \Delta I_L \times V_O}$ Eq-1(c)	$L_1 = L_2 = \frac{V_S \times (V_0 - V_S)}{f_S \times \Delta I_{L1} \times V_O}$ Eq-2(c)	$L_1 = L_2 = \frac{L}{2}$ Eq-3(b)

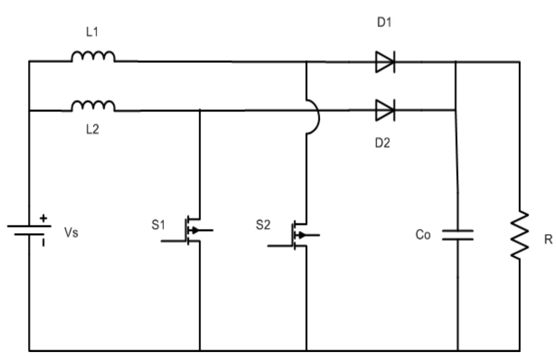

Fig 2 - polyphase boost converter

III. LITHIUM ION BATTERY

There are many type of battery available but lithium ion is one of the best battery available it have no self discharge issue as well as high concentrated energy which improve working on lithium ion battery. it has been used in several electronic gadgets, space craft and aircraft power system. To understand its dynamic behaviour a model is shown in fig 3 it have a set capacitor and resistor (Bhattacharya et al.2009).in this model it contains mainly three components.

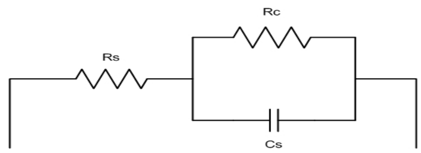

Fig 3 - Lithium ion battery

1) Electromotive force (EMF).
2) An internal resistance with two component Rs and Rc.
3) A capacitive nature that mainly comes from transient response of charging porous electrodes.

The equivalent circuit of lithium ion battery have ohmic resistance (HU, Li and Peng, 2012) the activation polarization resistance, the concentration polarization resistance and double layer capacitance. Rs represent activation polarization resistance. Cs exists on the surface of electrode and Rc is concentration polarization resistance.

A. *Polyphase boost Converter Integration with Lithium ion Battery*

Lithium ion battery if integrated with boost converter it have several complications. This may be overcome by the use of polyphase boost converter as fig.4 shown

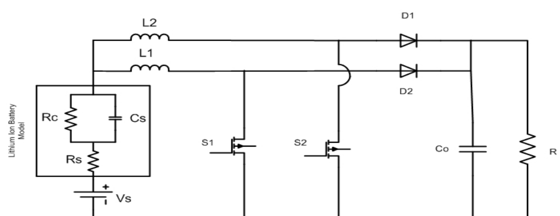

Fig 4. Lithium ion battery integration

The operation of polyphase boost converter depends on its duty ratio which is taken as D=0.5 in current analysis

1) *MODE -1*

($0 \leq T \leq T_{on}/2$) Then (S_1=ON & S_2=OFF)

In this interval inductor L_1 is in charging state and current across it will be rising nature (Di capua et al , 2017). While inductor L_2 (it has been assumed that it is already charged)and discharging its energy through load, the nature of current across it will be of decaying nature as shown in fig 5. The voltage across the inductor when S_2 is on inductor L_1 and L_2 is discharging is given by.

Across L_1:-

$$-V_S + V_{L1} + V_{RS} + V_{RC} + V_0 = 0 \qquad (1)$$

Across L_2:-

$$-V_S + V_{L2} + V_{RS} + V_{RC} = 0 \qquad (2)$$

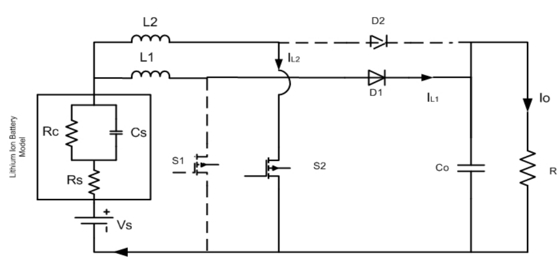

Fig 5 polyphase boost converter working($0 \leq Ts \leq Ts/2$)

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$Mode\ 2\left(\frac{T_{ON}}{2} \le T_S \le T_S\right) s_1 \quad off, s_2 \quad ON$

During this interval the inductor L_2 will be in charging state and current across it will be in rising nature. While inductor L_1,(it is already charged) will be discharging its energy through load, the nature of current across it will be of decaying nature as shown in fig 6 the L_1 and L_2 is discharging is given by.

Across L_1:-

$$-V_S + V_{L1} + V_{RS} + V_{RC} = 0 \qquad (3)$$

Across L_2:-

$$-V_S + V_{L2} + V_{RS} + V_{RC} + V_0 = 0 \qquad (4)$$

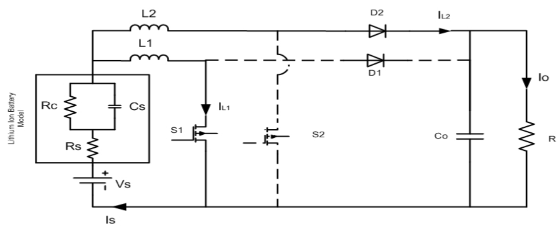

Fig 6 polyphase boost converter working (Ts/2≤Ts≤Ts)

The voltage across the inductor in a complete cycle is zero by solving equation we get.

$$(V_S - V_{RC} - V_{RS} - V_0)DT_S + (V_S - V_{RS} - V_{RC})(1-D)T_S \quad (5)$$

So the parasitic element reduces the output voltage by the correction factor given by.

$$V_0 = \left(\frac{V_S}{(1-D)} - \left(\frac{V_{RS}+V_{RC}}{(1-D)}\right)\right) \quad (6)$$

So in order to reduce loss across Rc the polyphase boost converter is used as the number of stages increases the source current frequency increases.

$$X_C = \frac{1}{2\pi f c_b} \qquad (7)$$

As the frequency increases capacitance (C_b) decreases and the current across the resistance decreases and it reduces loss. it also decreases the heating effect of battery (petr and max, 2018).

IV. SIMULATION RESULTS

In this proposed model of polyphase boost converter it consist of two inductor named L_1, L_2. The current across the inductor L_1 during charging (0≤ Ts ≤ Ts/2) varies from 0.1A to 1.5A while during discharging (Ts/2≤ Ts≤ Ts) it ranges from 1.5A to 0.1A which is depicted in fig 7. Moreover the magnitude of current across the inductor L_2 will remain the same having its waveform shifted by 180º from current L_1 as illustrated in fig 8.

As the source current is addition of current owing across the inductor $L_1$and L_2. The source current (Is) varies from 1.43A to 1.5A as illustrated in fig 9. While the voltage gains and current gain remains as conventional boost converter i.e. 29V and 0.8A is depicted in fig 10 and fig 11.

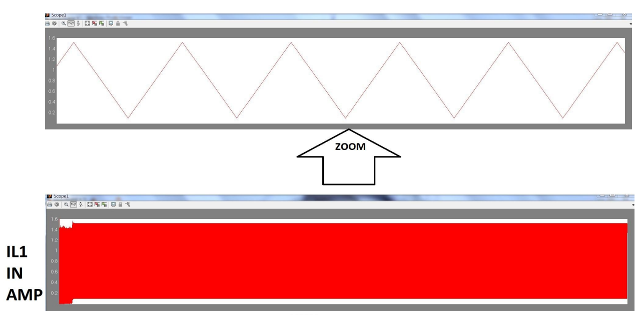

Fig 7 inductor current (I_{L1})

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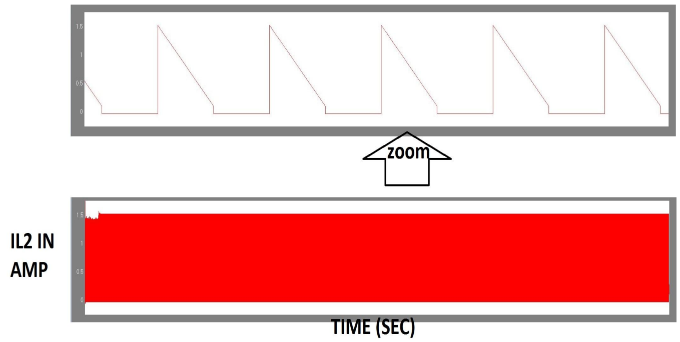

Fig 8 inductor current (I_{L2})

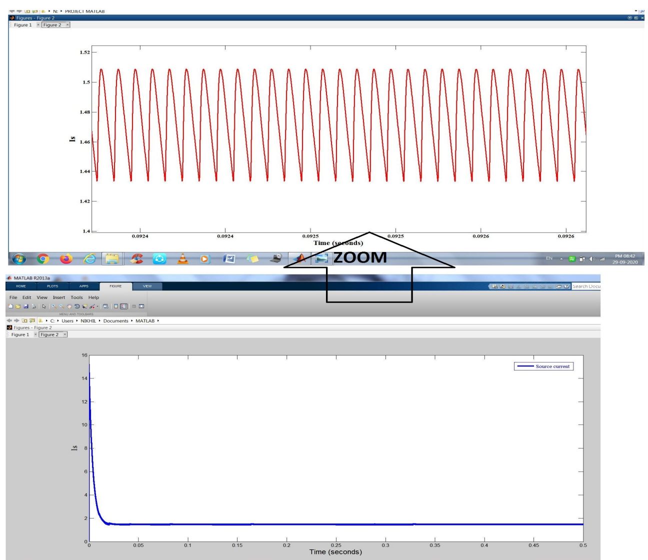

Fig 9 source current (Is)

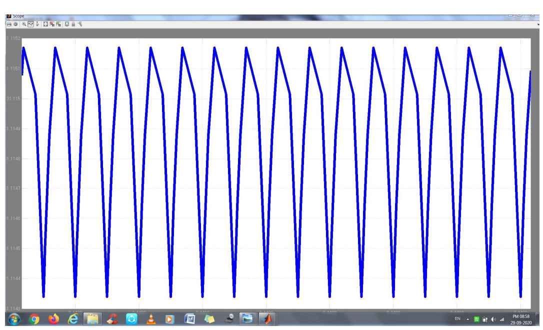

Fig 10 Load current

V. CONCLUTION

Polyphase boost converter (2 stage) has increased the frequency twice of switching frequency and this decreases the ripple of source current and which varies between 1.43 to 1.5 while the variation in inductor current between 0.1A to 1.5A. So the ripple has been reduced significantly when polyphase boost converter in integrated with lithium ion battery which causes less heating effect and hence increases the working durability.

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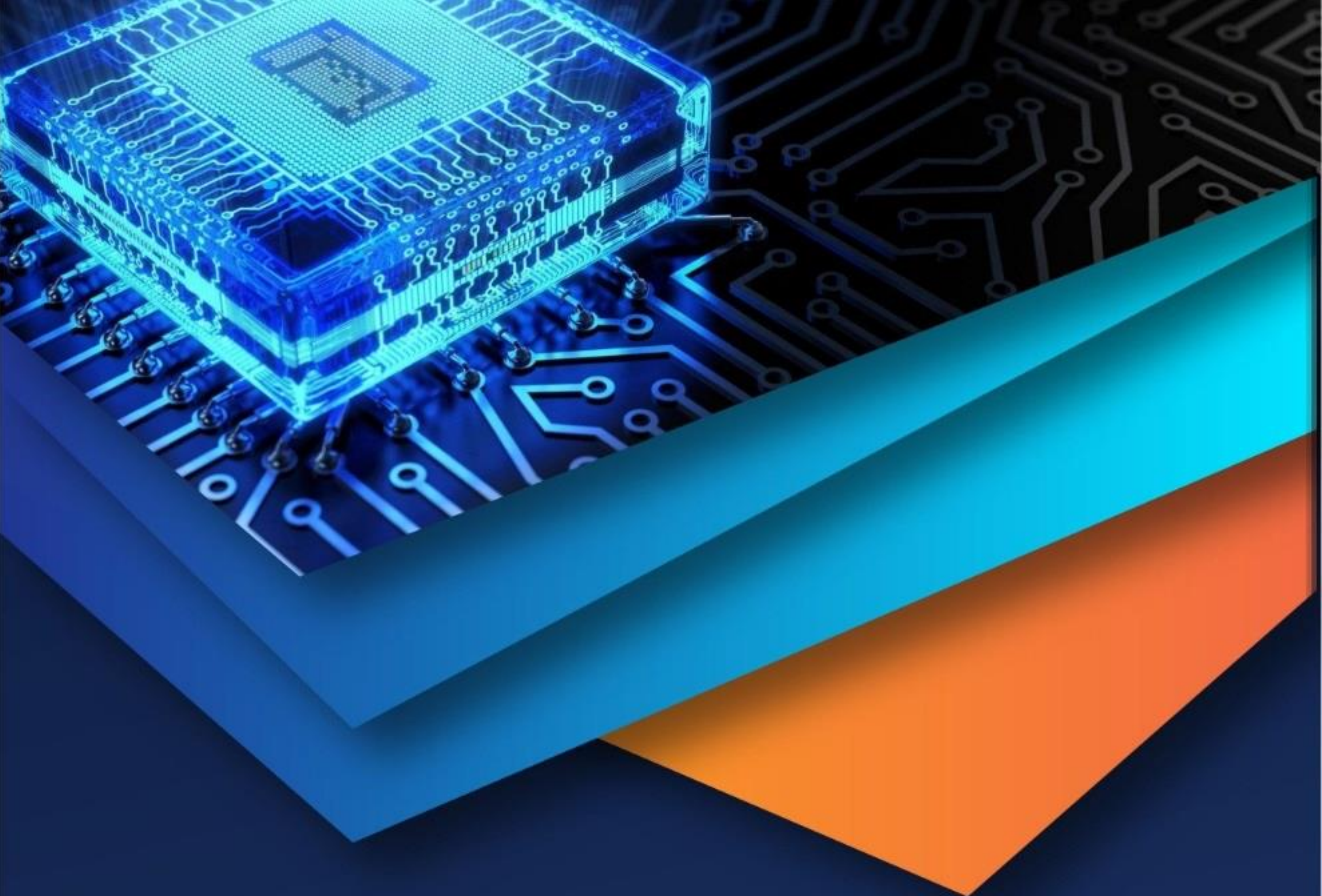

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