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Transient Analysis of A SEPIC Converter Under Peak Current Mode Control

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Abstract **- In this paper, the focus is on studying the behavior of a SEPIC (Single-Ended Primary-Inductor Converter) converter under the control of a peak current mode controller. We observe how the converter responds when subjected to sudden changes in load resistance and input voltage while operating in steady-state conditions. With the help of different simulation waveforms, such as time against load voltage, load current, and the sum of inductor currents, we can analyze the converter's performance.**

Keywords - SEPIC converter, Peak Current mode Controller, Variable Source Voltage, Variable Load Resistance.

I. INTRODUCTION

DC-DC converters play a crucial role in powering electronic circuits and managing energy transfer between DC systems. They are widely employed in diverse industrial environments where voltage stabilization is vital. Recently, there has been a notable focus on the Single Ended Primary Inductor Converter (SEPIC) topology due to its distinctive features, making it well-suited for applications that require a wide input voltage range. The SEPIC topology can function as either a step-down or step-up converter, depending on the duty cycle's value[1]. In [3] introduces a comprehensive examination of the SEPIC converter by utilizing Hysteresis Current Control and PI control methods. The main focus is on investigating Output Voltage Stability, Total Harmonic Distortion (THD), Power Factor (PF), and Efficiency. bifurcation analysis of a peak current control mode of SEPIC in the time of continuous conduction mode is described and performed. [4] presents an innovative, high-amplification, non-isolated, non-inverting, single-switch DC-to-DC converter that utilizes a modified SEPIC topology. Additionally, it incorporates a voltage multiplier unit into its design. The SEPIC dc-dc converter is renowned for its extensive use of energy storage elements, but it shows considerable nonlinearity due to feedback and switching characteristics that are common to all dc-dc converters. As a result, it has the potential to exhibit chaotic behaviour and other nonlinear phenomena, which have been thoroughly explored in recent research. Numerous control strategies have been examined, uncovering different types of bifurcation behaviours' within these systems[5-7].

In [8], transient and steady-state behavior is analyzed for different types of DC-DC converters, namely, Cuk, Sepic, Zeta, and Luo converters under open-loop conditions, and in [2], for the buck converter under closed-loop conditions.

The paper is arranged in the following manner. In section II for Peak current controlled SEPIC converter operation have been explained, in section III explains the transient and steady state behavior due to load resistance and input voltage variation and the conclusion has been drawn in section IV. All the simulations have been done in MATLAB Simulink.

By observing and analyzing the simulation waveforms, the paper aims to provide insights into the SEPIC converter's dynamic behavior under peak current mode control during steady-state operations and its ability to handle transient events related to load and input voltage changes. These findings could be beneficial in designing more efficient and reliable DC-DC converters for various practical applications.

II. SYSTEM DESCRIPTION

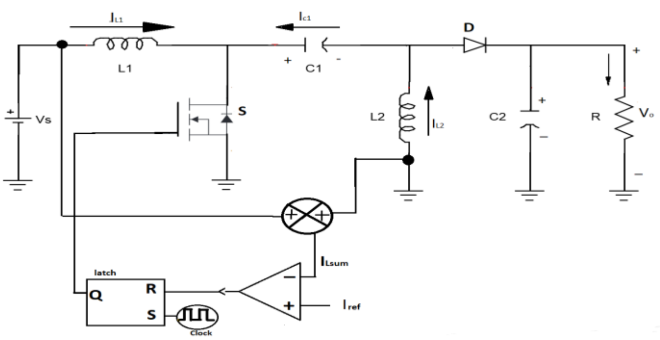

Fig. 1. SEPIC converter with a peak Current mode controller

The Fig 1. illustrates a peak current mode control technique employed in a SEPIC converter. At the start of a self-

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oscillating clock pulse with a time period of T, the switch is activated. In the implementation of current mode control for the SEPIC converter, it is typical to measure the switch current, which results from the combined currents of two inductors i.e., $i_{Lsum} = i_{L1} + i_{L2}$. This measured current is then compared with a reference current, I_{ref}. In Fig 2. the simulation waveform depicts the control signal, gate pulse and clock signal. At the starting of each clock pulse the gate pulse is also high and the gate pulse is high until the Sum of the inductor current reaches the reference current in this case I_{ref}= 1 A. As long as gate pulse remains high it will drive the switch S into on state. During ON state of the switch S thus creating a shorted path between the input voltage and the inductor1(L1), starts to charge. The load current is not directly supplied by Inductor 1 during this charging phase. Instead, the current to the load is supplied by a combination of Inductor 2(L2) and Capacitors 1 and 2. These components store energy when the switch S is OFF and the inductor current is decreasing.

When the sum of inductor currents reaches 1 amp, which is it becomes equal to the reference current the Gate pulse becomes low and the switch S turn OFF and the sum of the inductor currents starts to fall, since the current to the load is supplies by the stored charge of the capacitors thus a negative slope is observed.

It is seen form the above clock graph that at interval of 33.33µs a high signal is dispatched by the clock, which is actually driving the whole control circuit. When the clock hits high the gate pulse is again triggered to go high sending the signal to switch S to turn ON, thus shorting the path between inductor1 and the input supply there by again the rise is the sum of the inductor current is seen until it reaches the reference current

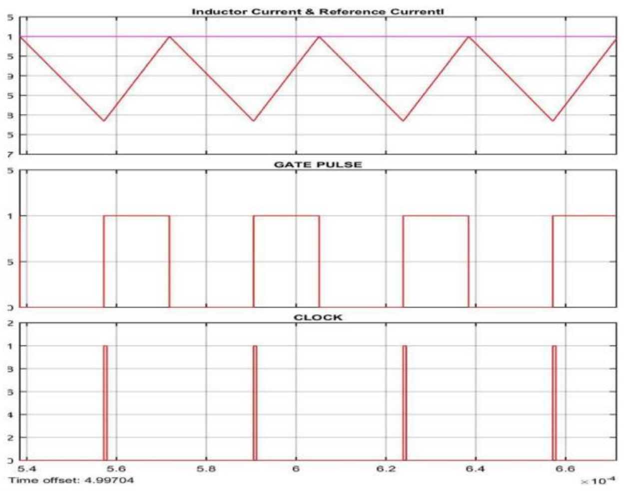


Fig. 2. Simulation waveform for control signal, gate pulse and clock signal.

III. OBSERVED RESPONSES AND DISCUSSION

For analyzing the performance of the controller and converter we have done here two case studies. In 1st case study we fixed the input voltage and varied the load resistance. And for 2nd case study we fixed the load resistance and input voltage varied. During each variation we observe nature of load voltage load current and sum of inductor current.

Following parameter values are consider for the performing simulation.

Table 1 parameters list

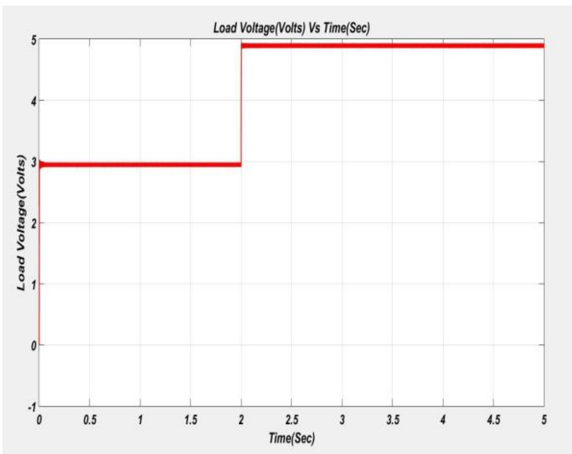
Parameters	Value
Inductor1 (L_1)	0.001H
Inductor 2(L_2)	0.001H
Capacitor 1(C_1)	100µF
Capacitor 2(C_2)	100µF
Reference Current(I_{ref})	1A
Switching frequency	30Khz

A. *Case Study 1: Variable Load and Fixed Voltage*

In this case study we have tried to observe that how the controller action and the converter response both reacts to a sudden load change while operating in steady state.

That is for how much time it is in transient period, and time taken by the converter to recover from the transient period without allowing much fluctuation in the output voltage. Since any fluctuation for more than few milliseconds outside the tolerance range of the components will result is damaging the component permanently.

For the simulation input voltage consider here 7.5V and The Load is steeped from 5Ω to 10Ω and all other parameters are chosen from Table 1.



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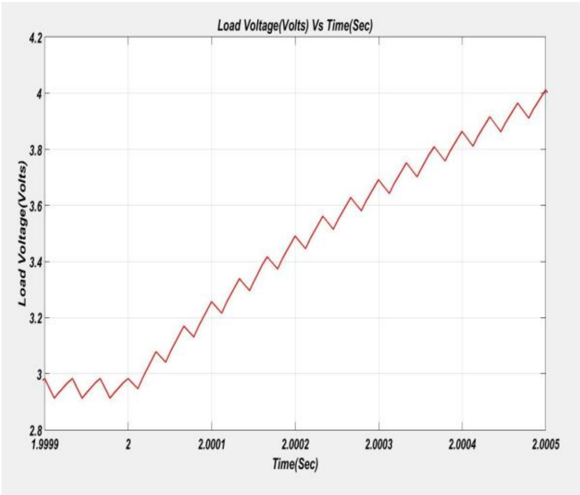

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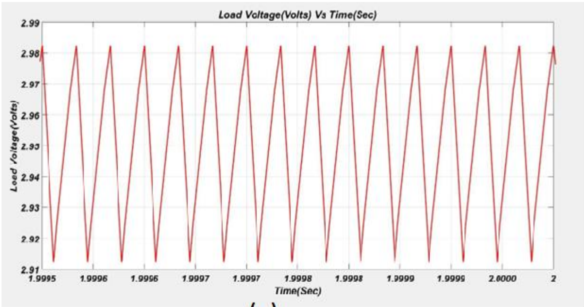

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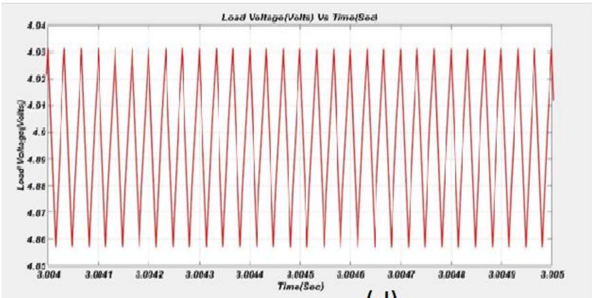
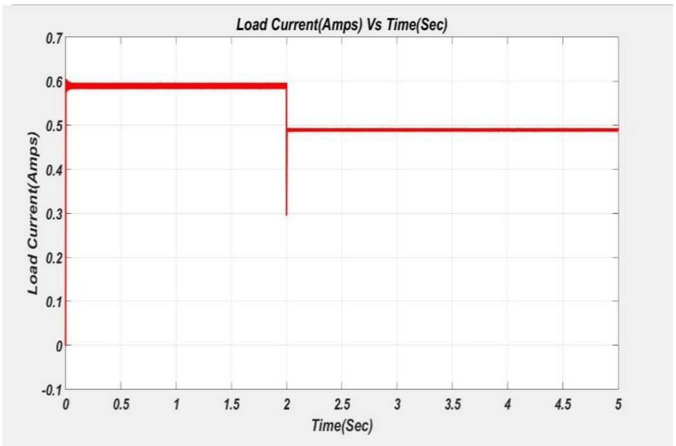


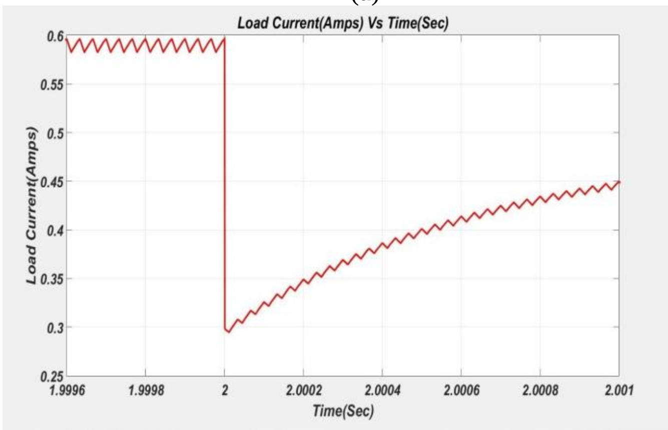
(d)

Fig. 3. (a) Load voltage waveform when load is stepped from 5Ω to 10Ω. (b) load voltage during transient period. (c)load voltage before transient at R=5Ω. (d) load voltage after transient at R=10Ω

The load suddenly gets doubled after 2 seconds of the simulation start time In Fig 3. (a) it is observed that till 2 sec the load voltage is steady(3V) and at 2 sec it enters transient state and recovers quickly and steady voltage(5V) is observed. A more magnified view will revile more details about the characteristics. Fig 3. (b) shows the nature of the load voltage at transient state at 2 second it is observed that the voltage across load increases since the load changes from 5 Ω to 10Ω.The load voltage suddenly increases from 3-volt to 5 volts as it enters the transient state and tries to again stabilize itself. It is observed that the load voltage again stabilizes itself within 0.0025 second i.e. 2.5 msec Hence the response of our designed system is quite fast and reliable. Load voltage after transient(Fig 3(d)) and load voltage before transient (Fig3.(c)) have similar nature as well as similar characteristics but the only difference is that both have different magnitude due to change in load from 5 to 10 Ω.



(a)



(b)

Fig. 4. (a) Load current waveform when load is stepped from 5Ω to 10Ω. (b) load current during transient period.

The Fig 4(a) show the nature of the load current for load stepped from 5 Ω to 10Ω at 2 second mark.

From fig 4.(b) we can view that the current drops suddenly to 0.29 Amps from 0.59 Amps as it enters the transient state and tries to again stabilize itself it is observed that the load current again stabilizes itself within 0.0025 second i.e. 2.5 msec Hence the response of our designed system is quite fast and reliable. This response also hints us that the controller which is designed to not let the inductor Currents to rise above the reference current is working properly.

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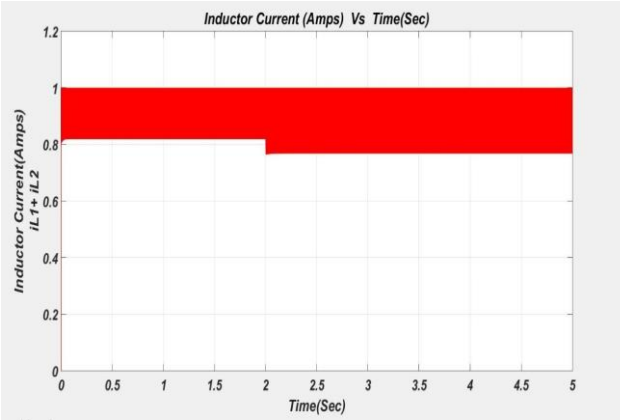
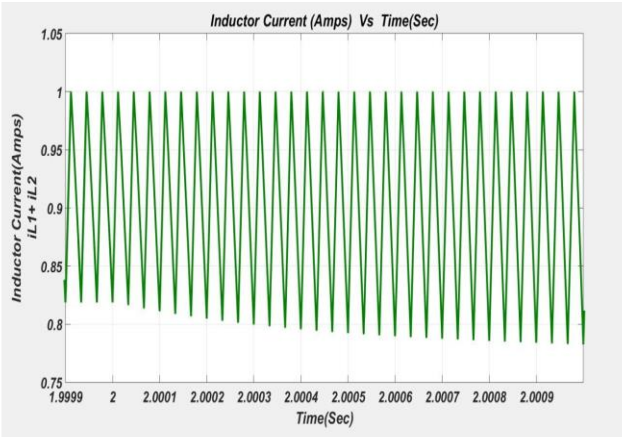


(a)



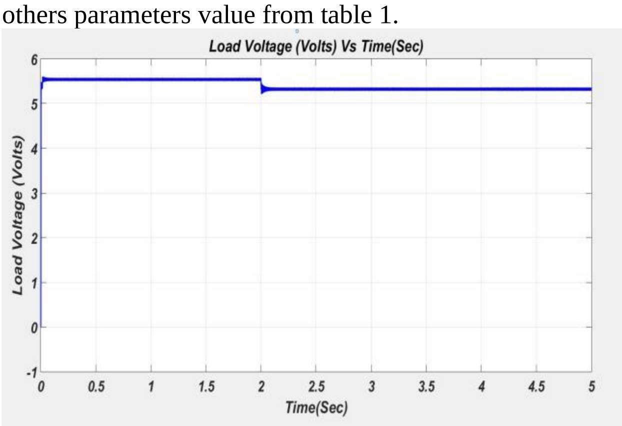
(b)

Fig. 5. (a) I_{Lsum} waveform when load is stepped from 5Ω to 10Ω. (b) I_{Lsum} during transient period.

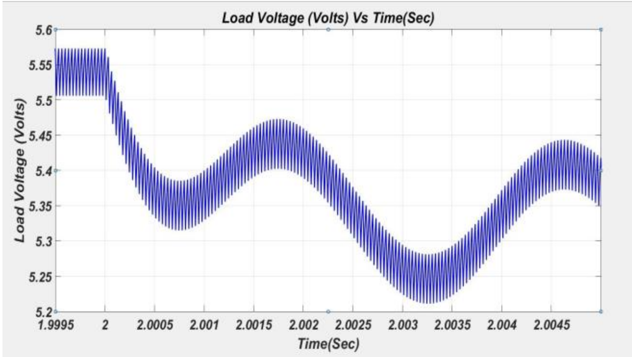
In Fig.5 (a) and (b) shows how the sum of the inductor current will respond to the sudden change of load resistance. It is clearly observed that the Sum of the load current never cross the reference current which is set at 1 amp thus obeying our controller logic which was explained before in governing logic of controller. It is seen that the system is in transient period for 1.5 msec and then the system stabilizes itself.

B. Case Study 2: Fixed Load and Variable Input Voltage.

In this case study we fixed the load resistance at 10Ω and varied the input voltage from 12V to 10V. We consider all others parameters value from table 1.



(a)



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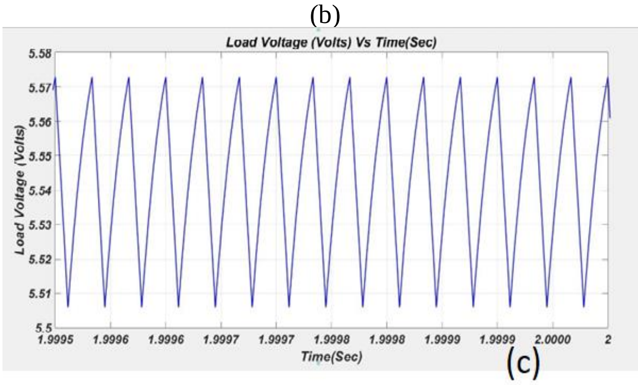


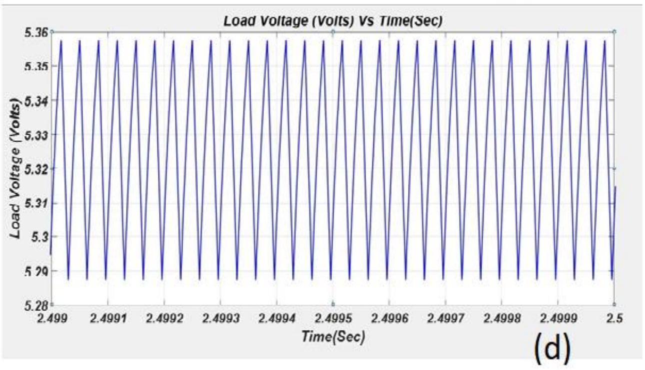
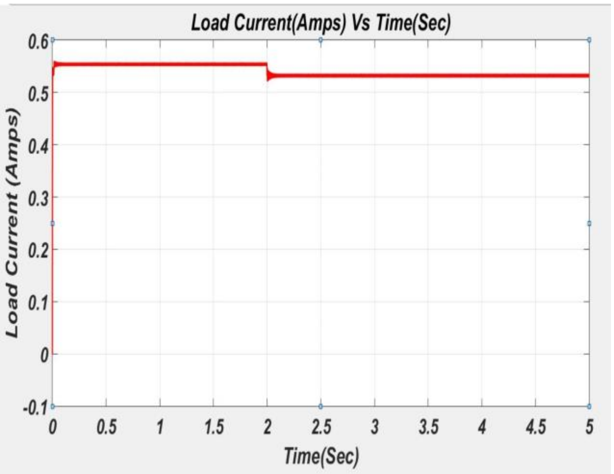


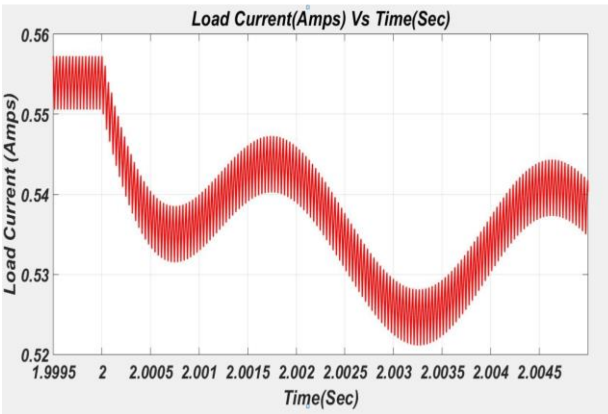
Fig. 6. (a) Load voltage waveform when input voltage is varied from 12V to to 10V. (b) load voltage during transient period. (c)load voltage before transient at Vs=12V . (d) load voltage after transient at Vs=10V

The fig6(a) and (b) show the nature of the load voltage and it is observed that it enters the transient period at 2 second due to input voltage variation from 12V to 10V and then recovers from the transient period within 0.1 second without much fluctuation.

Load voltage before transient(Fig 6(c)) and load voltage after transient (Fig6.(d)) we seen that both the nature of the waveform is same as well as a stable output voltage is observed. The only difference is the magnitude i.e. for 10V input the output voltage is low.



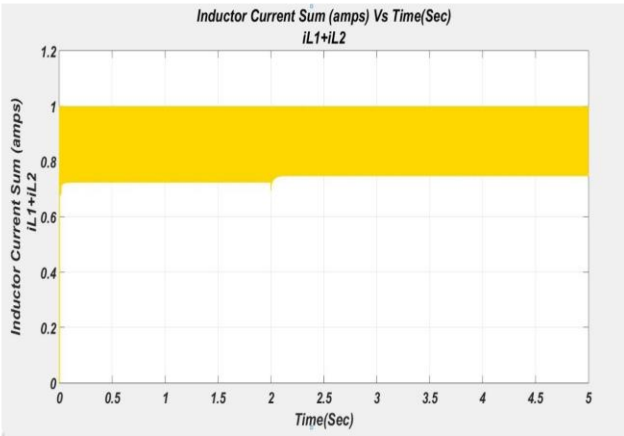
(a)



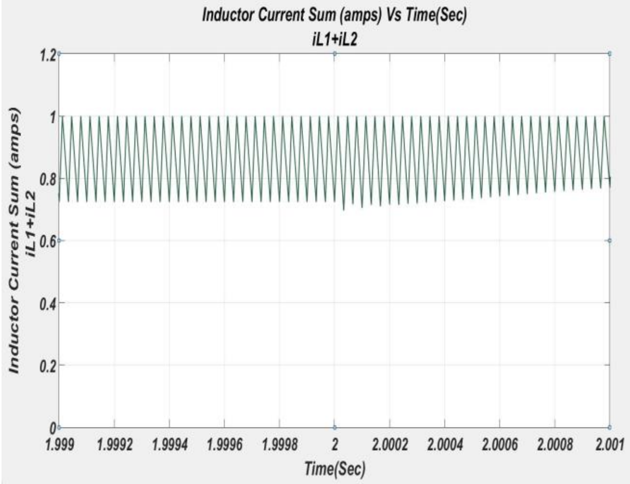
(b)

Fig. 7. (a) Load current waveform when input voltage is varied from 12V to 10V. (b) load current during transient period.

In the above fig(a) and (b) observed that till 2 sec the load current is steady and at 2 sec it enters transient state due to supply voltage variation from 12V to 10V and recovers quickly and steady current is observed. The Ccurrent through the load decreases due to change in input voltage.



(a)



(b)

Fig. 8. (a) I_{Lsum} waveform when input voltage is varied from 12V to 10V. (b) I_{Lsum} during transient period.

The fig. 8 (a) and (b) shows that in spite of having a change in input voltage the sum of the inductor current never crosses the reference current of 1 amp.

IV. CONCLUSION

From the case study 1, we observed that the system takes at very less time to get out of the transient state without any significant fluctuations in both load voltage and load current, and it does not exceed the reference current of 1 amp.

The simple conclusion drawn from this case study 2 that when the system is running in steady state at that time a sudden change of input voltage will set the system to go into the transient state. The system takes at very less time to get out of the steady state without any high fluctuation in both load voltage and load current this can be proven from the waveforms. Thus, these plots shows that our system reacts very swiftly to an abrupt change in load resistance and the system is capable of stabilizing itself with in a few milliseconds and without and high fluctuation thereby, protecting and sensitive equipment connected across load.

While the system when encounters any change of input voltage it reacts a little slow to the change when compared with load change

Hence, the above two case study proves that our designed system capable of handling both load change and input voltage change, efficiently while keeping the fluctuations under control.

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