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Effects of Passive Components on Designing a Three-Phase DC-DC Converter

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Abstract—This paper presents the impact of the inductor and exchanging recurrence of a three-stage DC-DC converter for potential application in an electric vehicle. The proposed DC-DC converter comprises the essential and auxiliary stages. The essential phase of the converter is made from total scaffold converter go about as information port which associated in equal, while at the auxiliary stage which goes about as yield port contained full extension rectifier associated in series. At the auxiliary stage, the channel capacitor, an inductor associated in corresponding to sift through the waves from the information voltage and produce a DC yield voltage that prompts better execution. Various phases of the DC-DC converter have been reenacted through PSpice and execution were assessed.

Keywords: *DC-DC, converter, three-phase, six inverters*

1. INTRODUCTION

The three-phase converter is suitable for low voltage and high current applications. [1]. A high step-up ratio converter is required to enable efficient energy exchanges between DC-DC of different voltages. Higher operating frequency leads to better transformer utilization and increases in power density [2].

The high isolated DC-DC converter is often used in a high gain application for protecting devices [3]. The converter is commonly used to convert the energy system in high voltage and high-power applications. Thus, the converter compatible with high voltage and high-power applications [4].

To overcome the problem across the switching of the converter, different clamping techniques were used, such as active clamping and naturally clamping. The proposed converters provide modular power conversion with modular high-frequency transformers and utilize high-frequency low-power transformers. This converter is suitable for high power and high voltage applications [5].

Three-phase converter proposing a high-frequency three-phase transformer, compared to single phase, the losses are well distributed. It is three times higher in the cutting frequency than the switching frequency, and the filter reduced its required size. The output current ripple is sufficiently reduced ripple frequency increases. Hence, the output filter can be much smaller [6].

In this paper, a three-phase DC-DC converter with six inverter performance was evaluated with the variation of the filter capacitor, an inductor with a different load. The effects of switching frequencies were also explored.

2. METHODOLOGY

The DC-DC converter that comprised of three phase converter. This three-phase converter consists of three full-bridge converters connected parallel at the input side and three full-bridge rectifiers connected in series at the output side. The function of the rectifiers is to convert the alternating current (AC) into direct current (DC). The series output connection is suitable for generating a high output voltage with relatively low PWM, which reduces the voltage stress of rectifier diodes, has high efficiency, and is suitable for low power applications.

Figure 1 shows a block diagram of the DC-DC converter that can be divided into two stages. At the first stage, it is comprised of three full-bridge converters and act as an inverter to generate AC output voltage from DC. Meanwhile, at the second stage, a rectifier is used to convert AC voltage into DC output voltage. Therefore, three full-bridge diode rectifier is used to generate desired DC output voltage from AC. The advantages of the full-bridge rectifier are that it does not need a center tapped transformer, thus will reduce the size and its cost. The output voltage of the rectifier at the first stage acts as an input voltage rectifier for the second stage.

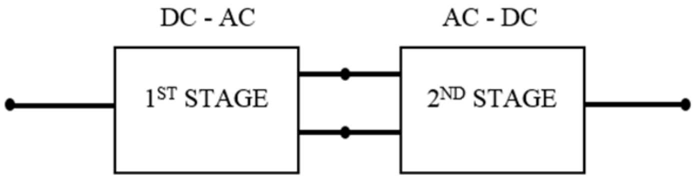

Fig. 1. System block diagram.

2.1 *DC-DC Converter*

Single-phase converter topology employs parallel one phase input and series output structure. Figure 2 shows the schematic diagram of a single-phase DC-DC converter. In this schematic, at the first stage of the converter, which is the primary side has one part of the full-bridge converter consists of an IRF150 rectifier connected to a voltage source. The second stage of the converter has a series output connection of a full-bridge diode rectifier. There have four diodes arranged in series labelled D1, D2, D3 and D4. During half cycle, only two diodes conducting current. During the positive half cycle, D1 and D3 conduct in a series while D2 and D4 conduct in reverse biased. The second stage converter is also comprised of the filter capacitor, filter inductor and load resistance. This single-phase converter works well, but for high power, the converter could suffer from current stresses.

They were adding one more part to the single-phase to obtain a two-phase DC-DC converter. As a result, the two-phase converter has a better improvement of the output voltage performances compared to the single-phase converter. Meanwhile, a three-phase converter is comprised of a single-phase and two-phase converter. A three-phase converter has low input/output ripple and low output voltage compared to a single-phase and two-phase. Therefore, three phases have better performance. The result of the various operating operations is illustrated in the simulation result.

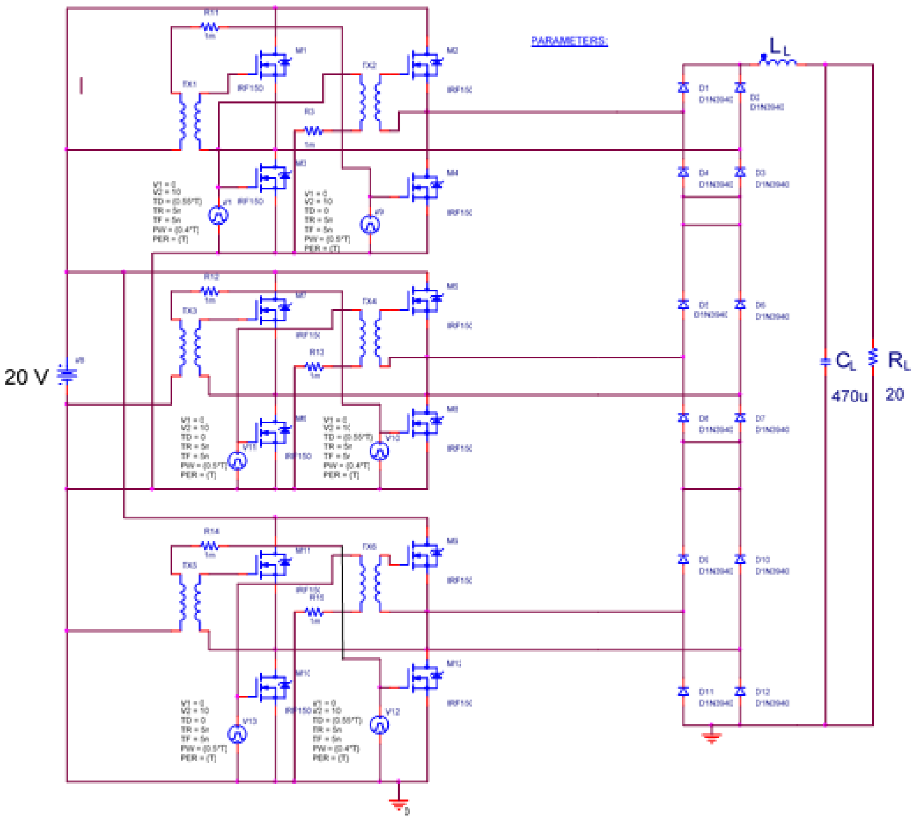

Fig. 2. Three-phase DC-DC converter.

3. RESULTS AND DISCUSSION

3.1 Effect of the Inductor on the converter

The analysis has been carried out to evaluate the converter operation. Simulations have been executed to see the effect of the inductor on the simulation result of single-phase, two phases and three-phase DC-DC converter. The frequency varies in range, from 100 kHz, 10 kHz and 1 kHz. Different frequencies result in the different output waveforms of the simulations. On the other hand, a different value of the inductor that varies from 100µH, 200µH, 400µH and 640µH also gives a significant impact on the results. The input and output voltage is constant. Results are shown respectively in Figure 3.

From the simulation results, when the inductor is at 100 µH with frequencies 10 kHz and 100 kHz, the output voltage ripples are relatively constant. The overshoot value is significantly lower, with a higher switching frequency at 100 kHz. For single-phase, as shown in Figure 3(a), based on the observation, the converter has a peak voltage around 21V and a short settling time with ripple at a frequency 1 kHz. The circuit settled around 2.4ms at the output voltage.

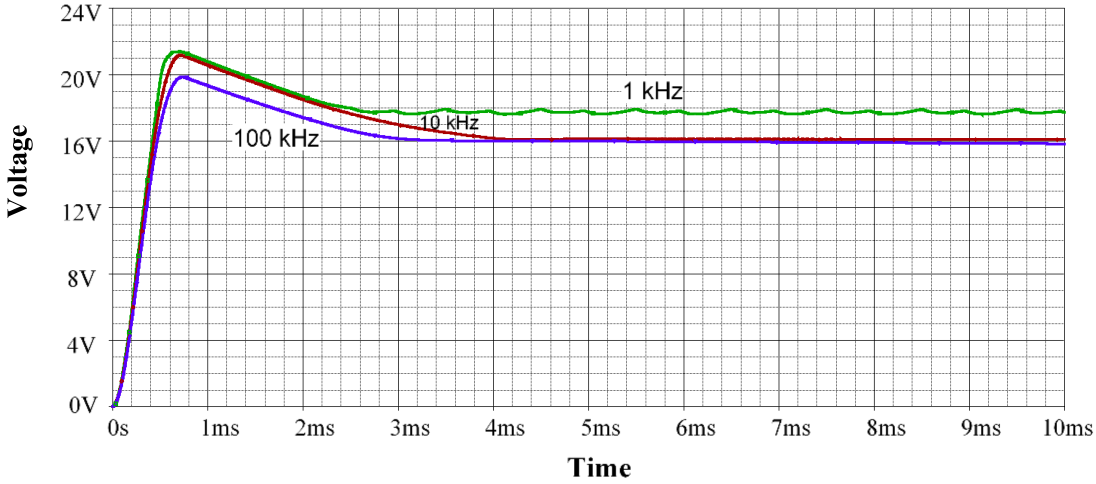

Fig. 3(a). Variation of the output voltage with frequency for single-phase converter with inductor L_f =100 µH.

For the two-phase converter shown in Figure 3(b), the peak voltage of the converter has slightly increased to 26V and have a longer settling time of around 3ms.

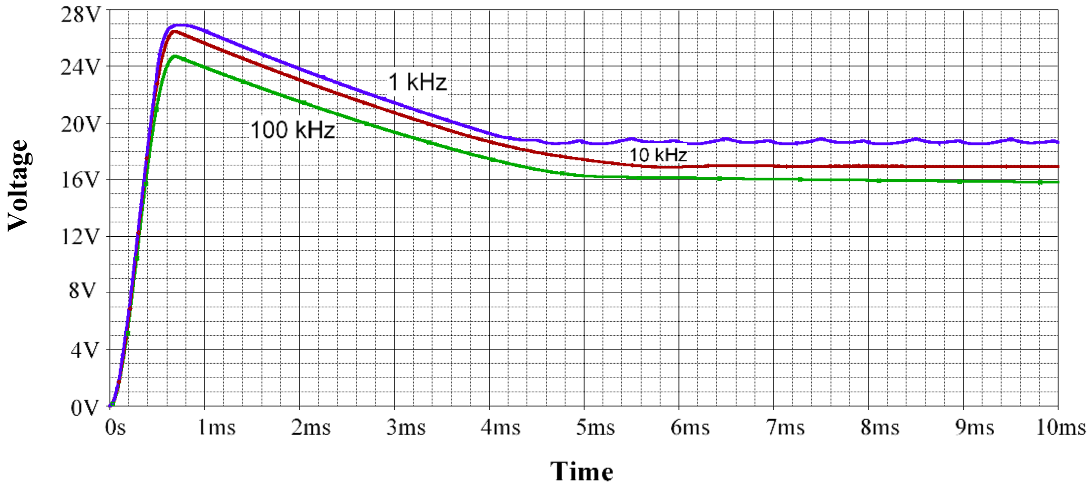

Figure 3(b): Variation of the output voltage with frequency for a two-phase converter with inductor L_f = 100 µH.

Meanwhile, in Figure 3(c), the three-phase converter shows peak voltage is sufficiently reduced compared with that in single-phase and two-phase converter, which is 12V.

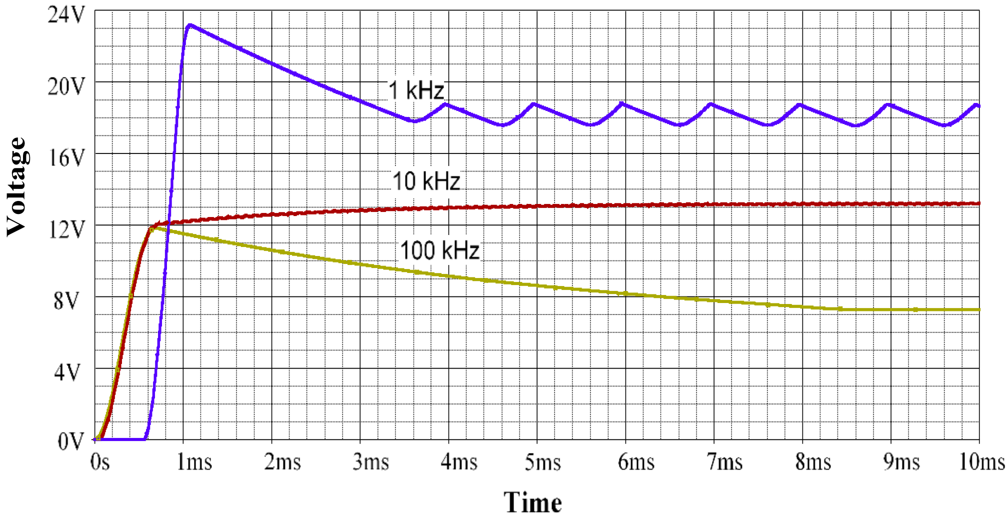

Fig. 3(c). Variation of the output voltage with frequency for a three-phase converter with inductor L_f =100 µH.

3.2 *Effect of the Frequency on the converter*

Simulations are carried out to see the effect of frequency, as shown in Fig. 4. The overshoot value is significantly lower, with a higher switching frequency at 100 kHz and inductor value at 100µH. The simulations result in single-phase represented in figure 4 (a) shows the output voltage ripples are low and the settling time settled around 4ms. Meanwhile, the value of voltage peak overshoots at 20V.

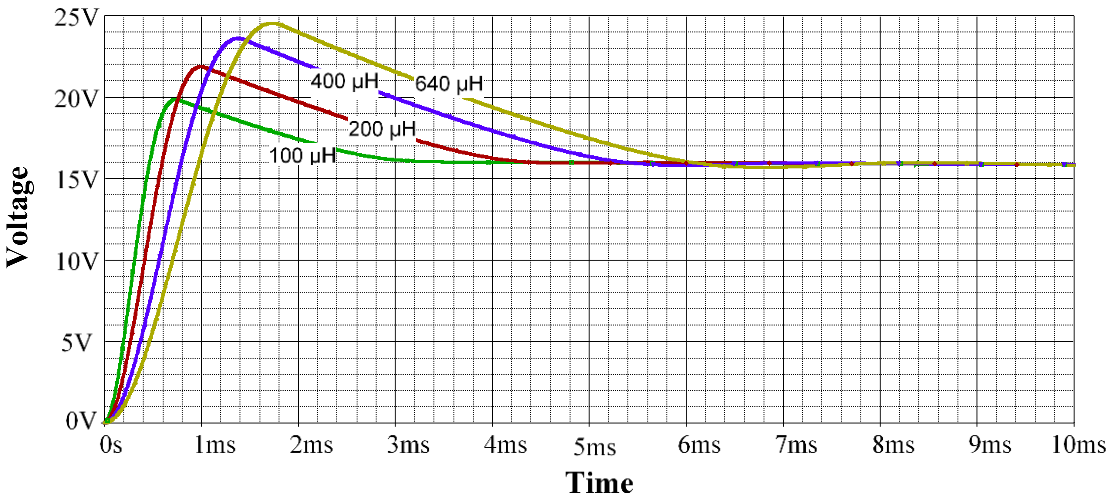

Fig. 4(a). Variation of the output voltage with an indicator for a single-phase converter with switching frequency fs=100 kHz.

The two-phase converter simulation result is illustrated in Fig. 4(b). The overshoot point is slightly increased. The output voltage shows at 25V and has a longer settling time, around 5ms.

The three-phase converter is shown in Fig. 4(c) as the most efficient because it lowers the output voltage. In conclusion, the higher the switching frequency value, the better performance of the simulation waveform will be achieved. On the other hand, it leads to better performance and increases the power density of the converter.

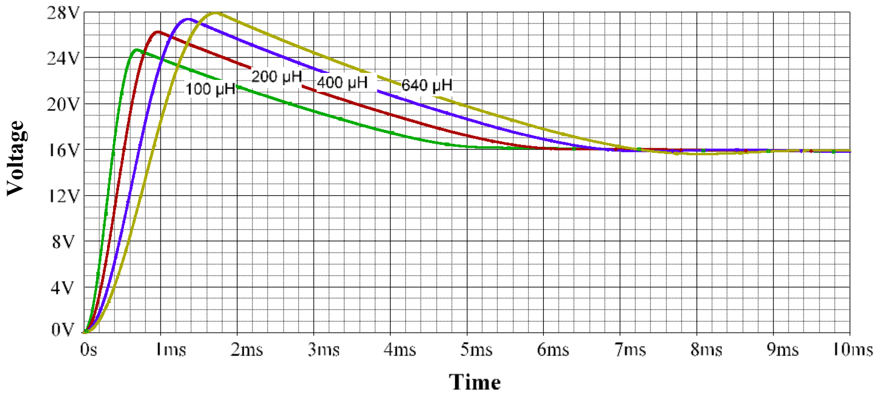

Fig. 4(b). Variation of the output voltage with an indicator for a two-phase converter with switching frequency fs=100 kHz.

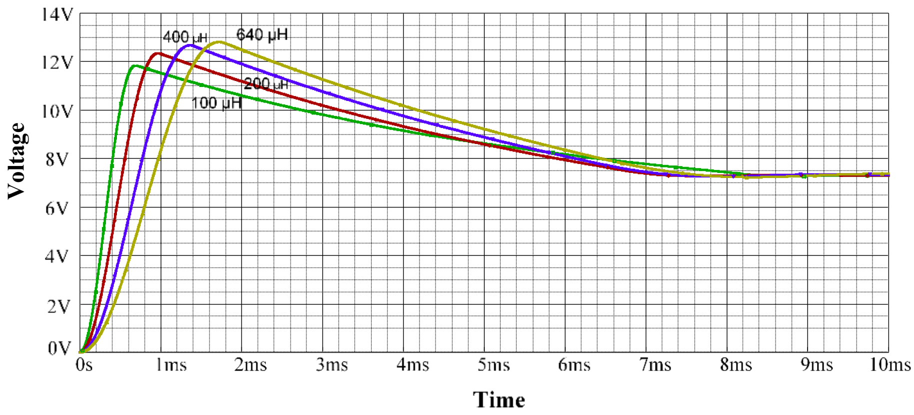

Fig. 4(c). Variation of the output voltage with an inductor for a three-phase converter with switching frequency fs=100 kHz.

3.3 Effect of the Frequency to Three Phase Converter

Figure 5 shows the effect of frequency to the simulation results. The value of inductor is 100uH, 200uH 400uH and 640uH and the frequency is varying from 100 kHz, 10 kHz and 1 kHz as shown in Figure 5(a-c). Based on the observation, frequency 100 kHz as shown in Figure 5(a) has better performance compared to frequency 10 kHz and 1 kHz. The overshoot point is significantly lower with the higher switching frequency. However, high frequency producing longer settling time.

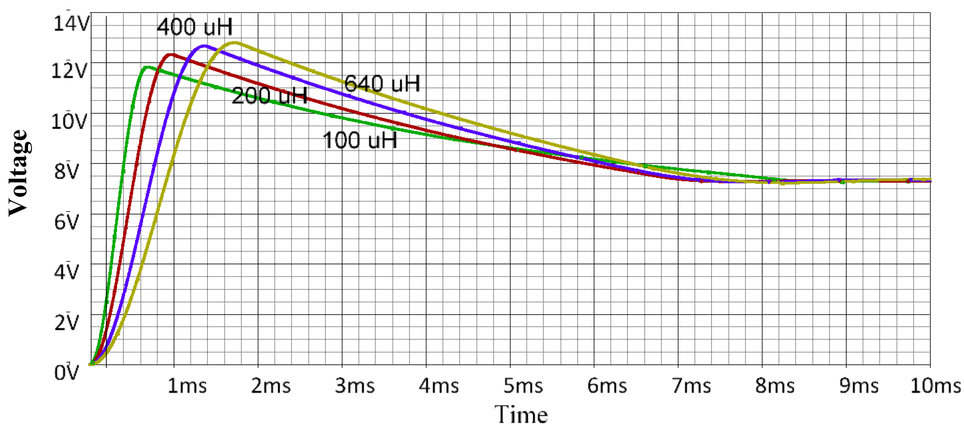

Fig. 5(a). Effect of the frequency to three phase converter for various inductors at 100 kHz.

Figure 5(c) when frequency is 1 kHz shows very undesirable output waveform with so many ripples. As can be seen from the output waveform, the overshoot point started a little bit late which at 0.6 ms instead of start form 0. Clearly the overshoot point is higher than the frequency of 10 kHz and 100 kHz. However, it has shorter settling time. On the other hand, the overshoot value is significantly lower with the higher switching frequency. The benefit of high frequency is lower ripple waveform.

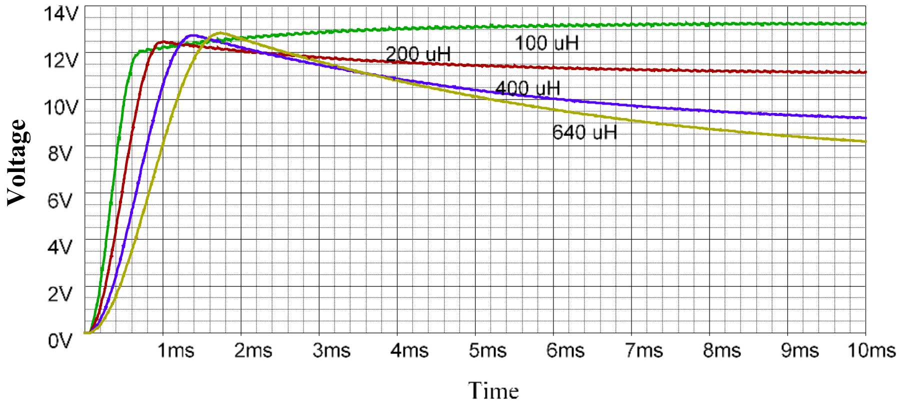

Fig. 5(b). Effect of the frequency to three phase converter for various inductors at 10 kHz.

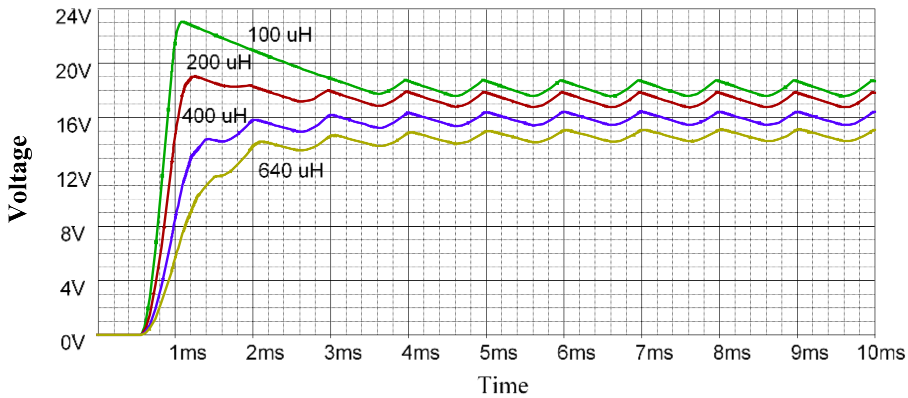

Fig. 5(c). Effect of the frequency to three phase converter for various inductors at 1 kHz.

3.4 Effect of the Load Resistance the converter

Figure 6 shows the effect of the load resistance on the simulation. We also need to consider the effect of load resistance. The load resistance varies from 20, 40, 60 and 100 Ωs, the value of the inductor of 640µH and frequency is at 100 kHz. From the observation, the converter needs to have minimal load resistance to handle the DC output voltage.

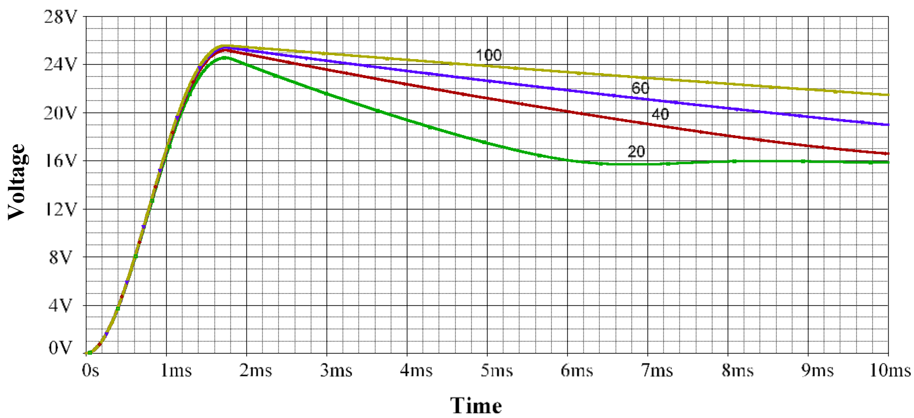

Fig. 6. Effect of the load resistance of the output stage.

3.5 Effect of the Capacitor on the converter

Figure 7 shows the output capacitance affect the stability of the converter. The capacitance can significantly influence the converter, which defines the stability of the converter operation. The filter capacitor is to convert the rippled output of the rectifiers into a smooth DC output voltage. The parameter has to be in a certain range to assure the stability of the system. As the capacitance value of 100uH, the voltage peak is at 26V and settled at 2ms with small oscillation. Increase the value of the capacitor to 470μF; we can see the peak value is around 24V and have the smooth output waveform. Hence, it is crucial to consider the value of the capacitance, which will determine the number of ripples at the output waveform. If the capacitance value is too low, it will have little effect on the output waveform.

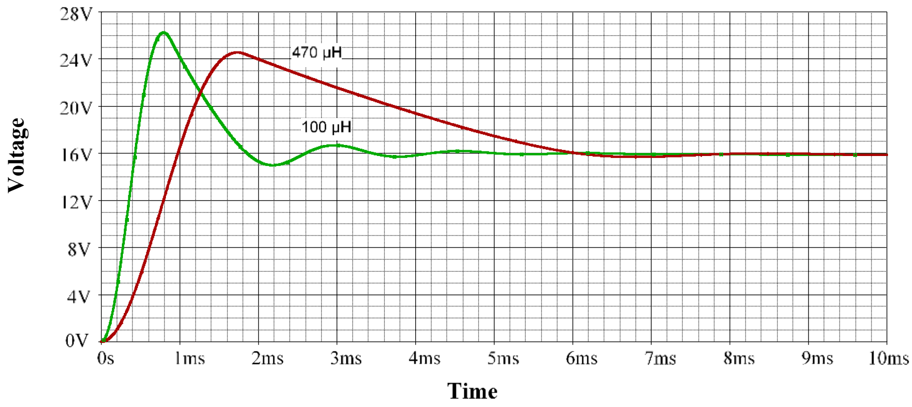

Fig. 7. Effect of the filter capacitor in the output stage.

3.6 Output voltage after rectification

Figure 8 shows the output voltage after rectification and before filter and after the filter. The output voltage after rectification is displayed in figure 8 shows the simulation result before filter when current is not passing through the inductor.

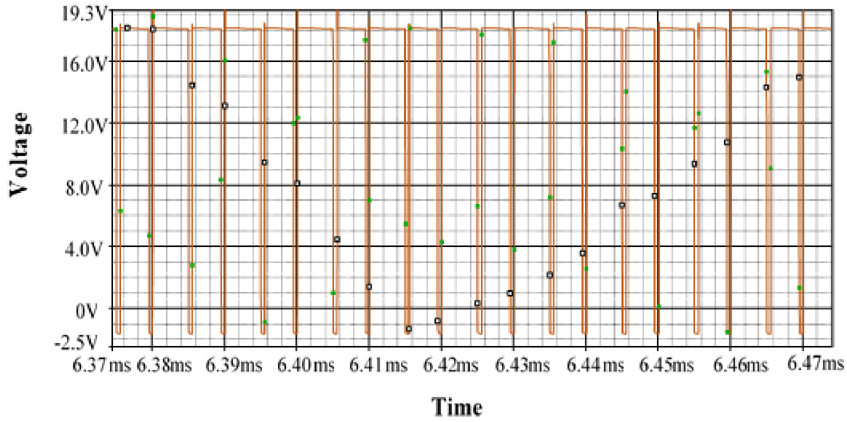

Fig. 8. Output voltage without a filter.

Meanwhile, as can be seen in Fig. 8, it shows the simulation result after filter when the current passing through the inductor. The output of the after rectification has less ripple and produced a smooth output waveform.

3.7 Load current

Figure 9 shows the load current in the inductor. The ripples are not only determined by the smoothing capacitor but load current is also important to determine the ripples of the output waveform. We have to consider the parameter of the load current to obtain a smooth output waveform of the simulation. Figure 10 shows the inductor current peak value is at 11.2A.

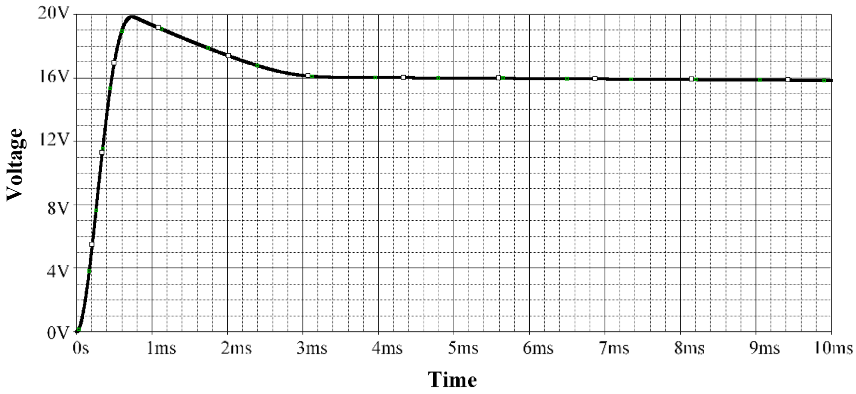

Fig. 9. Output voltage after the filter.

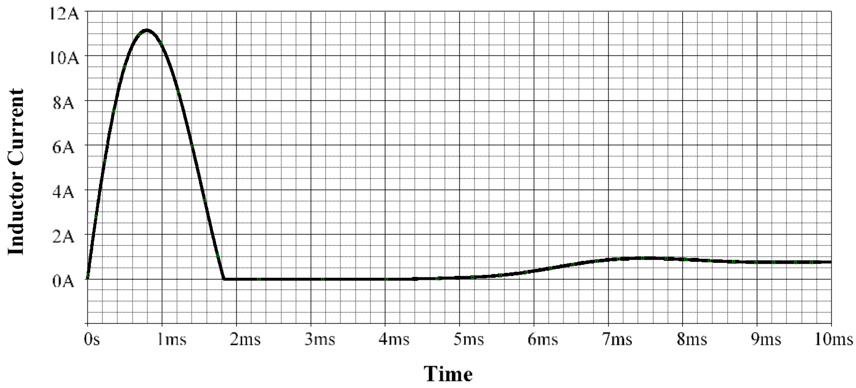

Fig. 10. Load current before the inductor

The inductor current is pulled down, as shown in Fig. 11, after the load current passing the inductor. It shows that the load current reaches the minimum value and inductor current becomes zero after a short period of time.

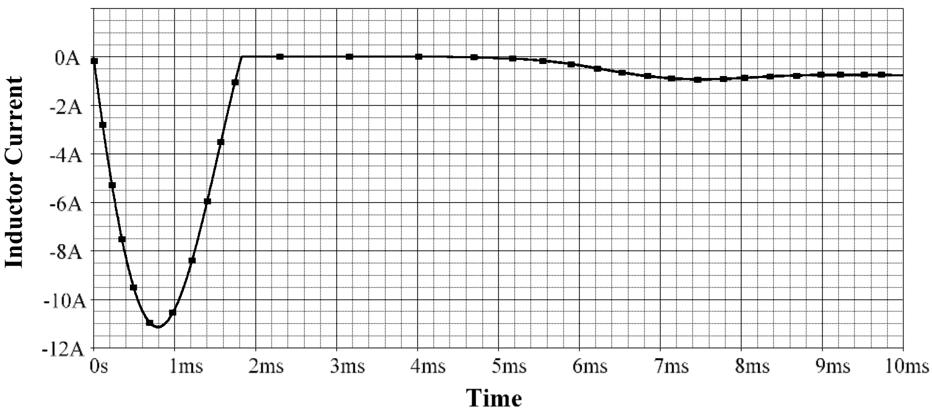

Fig. 11. Load current after the inductor

4. CONCLUSION

The simulation of the DC-DC converter has been done for designing various phases. The DC-DC converter can be operated at different phases, first is a single-phase, then two phases and lastly, three phases. The performance of the converter is simulated using PSPICE simulation software, and the performance is evaluated accordingly based on the switching frequency (f_s), which varies from 1 kHz, 10 kHz and 100 kHz, inductor (L_f), which varies from 100uH, 200uH, 400uH and 640uH, filter capacitor (C_f) selected as 470uH, load resistance and load current. The input voltage (U_{in}) used for this converter is 20V and the output voltage varies from 20V up to 100V. This converter simulation result shows better performance compared to the proposed converter from the previous study. Features such as high switching frequency and high capacitance value make this converter better in performance.

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