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Modular Zigzag Converter Based Power Quality Improved SMPS for Arc Welding

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Abstract

This paper deals with reduction of Total Harmonic Distortion (THD) in the AC Mains by implementing the power factor corrected (PFC) ZigZag Converter for multiple output Switch Mode Power Supply (SMPS) circuit. The system consists of converting single phase supply voltage into multiple output DC voltages. In this work ZigZag converter which is DC – DC converter is operated in various modes from which best selection is done which is suitable for many industrial applications. Another converter is cascaded with Zigzag converter to convert one level of voltage into multiple levels of DC Voltages. Finally the test results are obtained in MATLAB software ZigZag converter operating in different Modes.
Keyword- Zigzag Converter, Switch Mode Power Supply, Power factor Correction, Total Harmonic Distortion, Operating Modes

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I. INTRODUCTION

All Switch mode power supply (SMPS) is finding the applications in personal computers (PCs), arc welding power supply, mobile phone chargers, security system (closed circuit cameras), support supplies with PLC's, aircraft communication system etc. there is large distortions which leads to the high total harmonic distortion (THD) in existing system so it need to be replaced with efficient system to improve total harmonic distortion (THD) in ac mains.

Switch mode power supply has many application in personal computer, arc welding, etc. Switch mode power supply is best choice for DC-DC converter used in computer which converts available unregulated ac to regulate multiple dc voltage to provide power to different parts of computer [1]. It is also used for arc welding power supply which draws highly distorted current with low power factor so to enhance the efficiency Zigzag is implemented [2]. Among the entire dc-dc converter topology Zigzag converter is 4th order which is a combination of buck-boost converter which provides less pulsating current [3]. The Zigzag converter is mainly adapted to reduce the total harmonic distortions (THD) in line current which improves the pulsating current in input side of it [1-3]. The power factor improvement of converter is achieved by designing power factor correction (PFC) circuit and be placed in front of the converter [4].

II. SYSTEM CONFIGURATION

Figure 1 shows the system of power factor corrected Zigzag converter employing to the switch mode power supply (SMPSs).The system consist of diode bride rectifier to convert the ac supply to DC with L-C filter to make ripple free dc. This dc voltage is feed to the front end Zigzag converter. Zigzag converter is operated in different mode of operations in discontinuous conduction. The advantage of discontinuous mode of operation is the reduction of voltage and current sensing devices also reduces the stresses on the devices and saturation problem. PCs need one voltage sensor for sensing as well as control so discontinuous mode of operation is preferable.

Zigzag converter consists of input and output inductors with intermediate capacitor, diode and high frequency switch. The next stage of filter circuit is Zigzag converter which is mediator between ac supply and SMPS circuit. It is operated in three different modes of operation with making its one of the component from L_1, L_1, and C in discontinuous conduction. The best operating mode is considered for PFC ZIGZAG converter among them. Voltage is regulated by regulating the duty cycle of converter. This regulated dc voltage is being given to the isolated converter. Multiple output dc voltage is driven from the isolated converter which is consisting of two capacitors and high frequency transformer. Multiple outputs are driven from the isolated converter from which one is directly sensed while other output voltages are controlled by the duty cycle.

III. MODES OF OPERATION

Zigzag converter is operated for SMPS circuit to analyze its performance for various operating modes for the selection of best mode of operation. The average output voltage in discontinuous state is more compare to continuous conduction mode so Zigzag is operated in discontinuous conduction. Converting 220 V into 3.5 V for domestic appliances and other loads is one we can use safely [5].

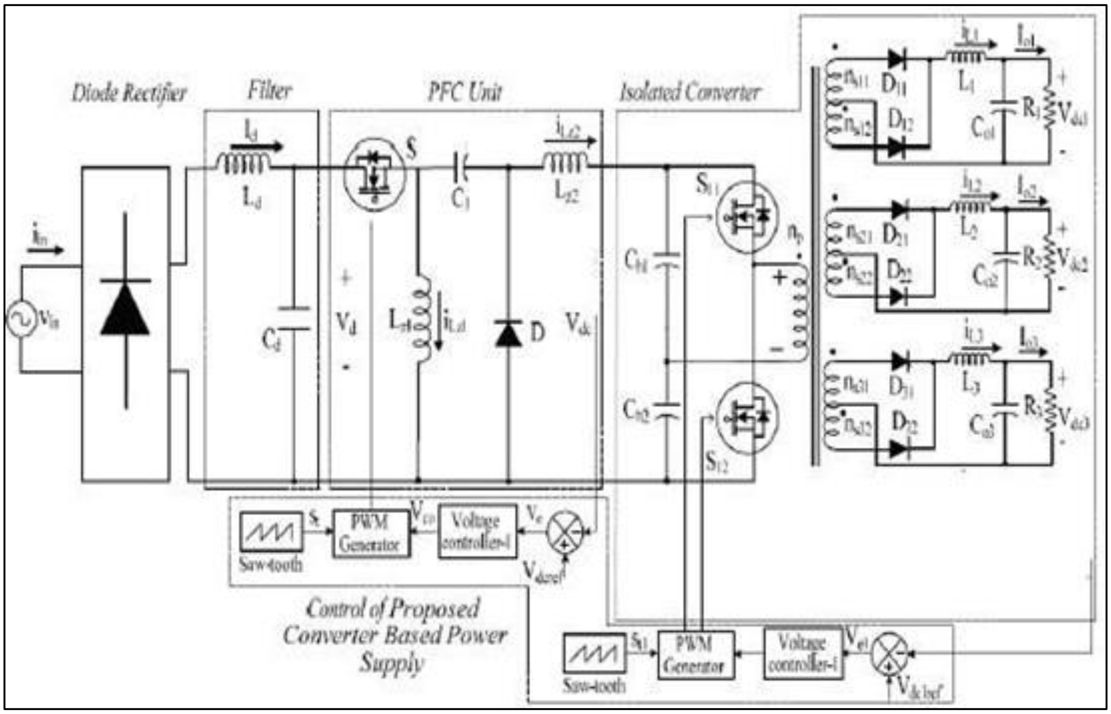


Fig. 1: Zigzag converter for SMPS circuit

A Input induction is in DCM

In output inductor is non-zero in one switching cycle. Operated as L1 in discontinuous and L2 with C in continuous mode. This mode is operated in three stages. The Stages are as follows.

1) Stage 1:

Initially current in the two inductor components rises with capacitor voltage becomes low. Realization the switching state of each component.

2) Stage 2:

In this condition diode D free wheels the energy to the capacitor which in turn increases voltage across it while rate of change of current to the both inductors are almost zero.

3) Stage 3:

Actual realization of first mode of operation which deals with discontinuous state of L1 . Also switch and diode are off in this state for one switching cycle and waits for next PWM cycle.

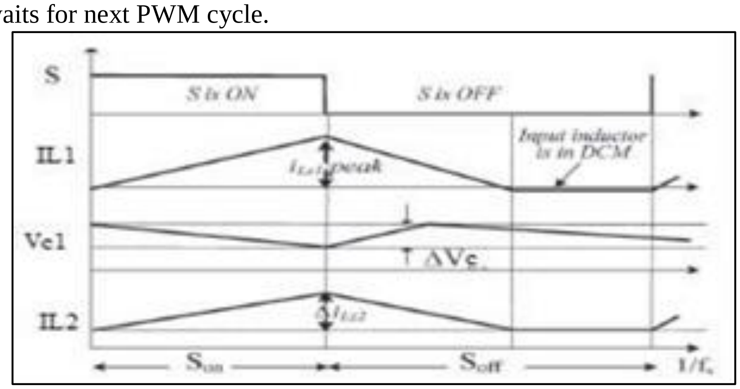


Fig. 2: Ideal waveform for input inductor L1 in DCM

Capacitor is in DCM

Zigzag converter is in operation with the middle capacitor C is in discontinuous conduction mode in one switching cycle which makes other two inductors is in CCM. This mode is operated in three stages. The Stages are as follows.

1) Stage 1:

The input and output inductor L2 is in charging state with capacitor C is in discharging when the switch is on. During this state output capacitors CI1 ? CI2 voltage increases.

2) Stage 2:

Energy input to the one of the inductor increases while the other output inductor component decreases in this stage of operation. The isolated converter is supplied with the L2 of Zigzag converter with zero voltage of capacitor.

3) Stage 3:

In this state continuous conduction is made. Energy in the L1and L2 which is the components of Zigzag converter decreases by some of more amounts. And capacitor of Zigzag is supplies with more amount of voltage.

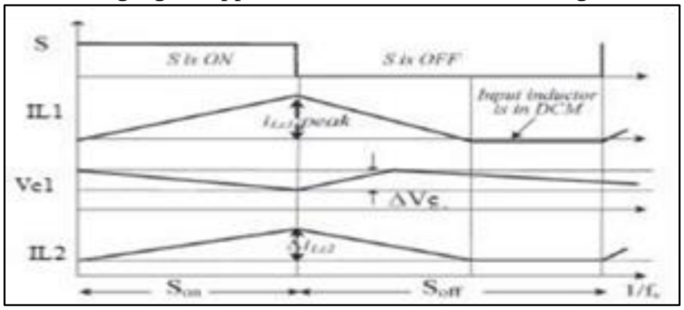


Fig. 3: Ideal waveform for capacitor in DCM

C $utput inductor is in DCM

In one switching cycle three different state have been analyzed when output inductor L2 is in DCM and input inductor L1 and capacitor C is in CCM. Which provides the desired of operation Zigzag converter. This mode is operated in three stages. The Stages are as follows.

1) Stage 1:

During this state both inductors L1 and L2 are in charging mode with switch S is ON and voltage across capacitor decreases.

2) Stage 2:

In this stage diode D freewheels energy across the capacitor dc-dc converter .While amount of energy of two other components decreases by more amount. Current i_{L1} becomes equal to negative of current i_{L2} in this state.

3) Stage 3:

In this interval both switch S and diode D is off. output inductor does not revolt with current at all ensuring DCM of L_2.

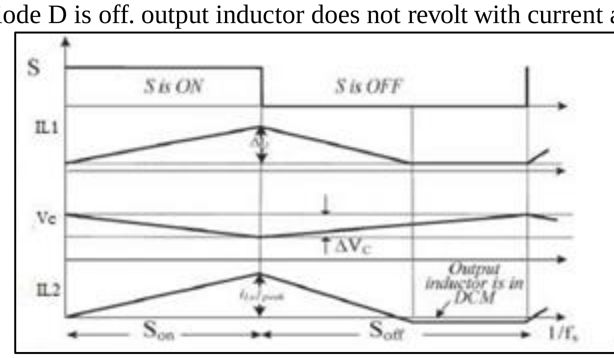


Fig. 4: Ideal waveform for output inductor is in DCM

IV. DESIGN SPECIFICATION OF ZIGZAG

Converter Design of Zigzag converter is based on various components as input inductor, middle capacitor and output inductor. Each component are calculated with the duty cycle of converter. As well as Zigzag converter buck, boost, cuk converters can also be employed for dc-dc conversion among all Zigzag provides the efficient result [6].

This duty cycle is calculated as

$$\alpha \; @ \; \frac{V_{dc}}{V_s+V_{dc}}$$

Whereas V_{dc} is first stage converter output voltage. Values of the components of Zigzag converter are calculated with rms supply voltage, dc output voltage of Zigzag converter and input power 350 w and duty cycle for CCM and DCM. Currently the use of low power application has been increased for which we require supply which is distortion free so we use converters which operates in discontinuous mode [7].

In DCM the values are as follows,

$$L_1 \; @ \; \frac{V_d^2}{2P}\left[\frac{V_{dc}}{V_s+V_{dc}}\right]$$

$$@ \; \frac{50\mu s(133.1\,V)^2}{2*350\,W}\left[\frac{300V}{(1.414*170)+300V}\right]$$

@ 0.@2 mH

$$C_1 @ \frac{Vdc\ast T}{2(Vdc+Vs)^2}$$

$$@ \frac{60\mu S\ast 360W}{2(300V+270\ast 1.414)^2}$$

@ 1@.@24 nF L_2 @

$$@ \frac{(183.16+183.16)\ast 300v\ast 60\mu s}{0.5\ast 2.06\ast 1.414}\left[\frac{300\ V}{170\ast 1.414+300V}\right]$$

$$\frac{}{\Delta Is}\ \frac{}{[Vs+Vdc]}$$

= 1.15 mH

In CCM the values are as follows, L_1 @

$$\frac{Vs\ T}{\Delta Is}\left[\frac{Vdc}{Vs+Vdc}\right]$$

$$@ \quad] \quad \frac{1.441\ast 170\ast 60\ \mu s}{0.20\ast 2.06\ A\ast 1.414}\left[\frac{300\ V}{1.414\ast 170\ V+300}\right]$$

@ 4.603 mH

$$C_1 @ \frac{\alpha TVdc}{2\Delta Vc1R}$$

$$@ \frac{TVdc}{2(\Delta(Vdc+Vs))(Vdc^2/Pin)}\left[\frac{Vdc}{Vs+Vdc}\right]$$

$$@ \frac{TPin}{2(\Delta(Vdc+Vs))(Vdc+Vs)}$$

$$@ \frac{60\mu S\ast 360w}{2(0.3(300V+270\ast 1.414))(300V+270\ast 1.414)}$$

$$L_2 @ \frac{Vdc\ T}{\Delta Is}\left[\frac{Vdc}{Vs+Vdc}\right]$$

$$@ \frac{300\ V\ast 60\mu S}{0.5\ast 2.05\ A\ast 1.414}\left[\frac{300V}{170\ast 1.414+300V}\right]$$

@ 5.7456 mH

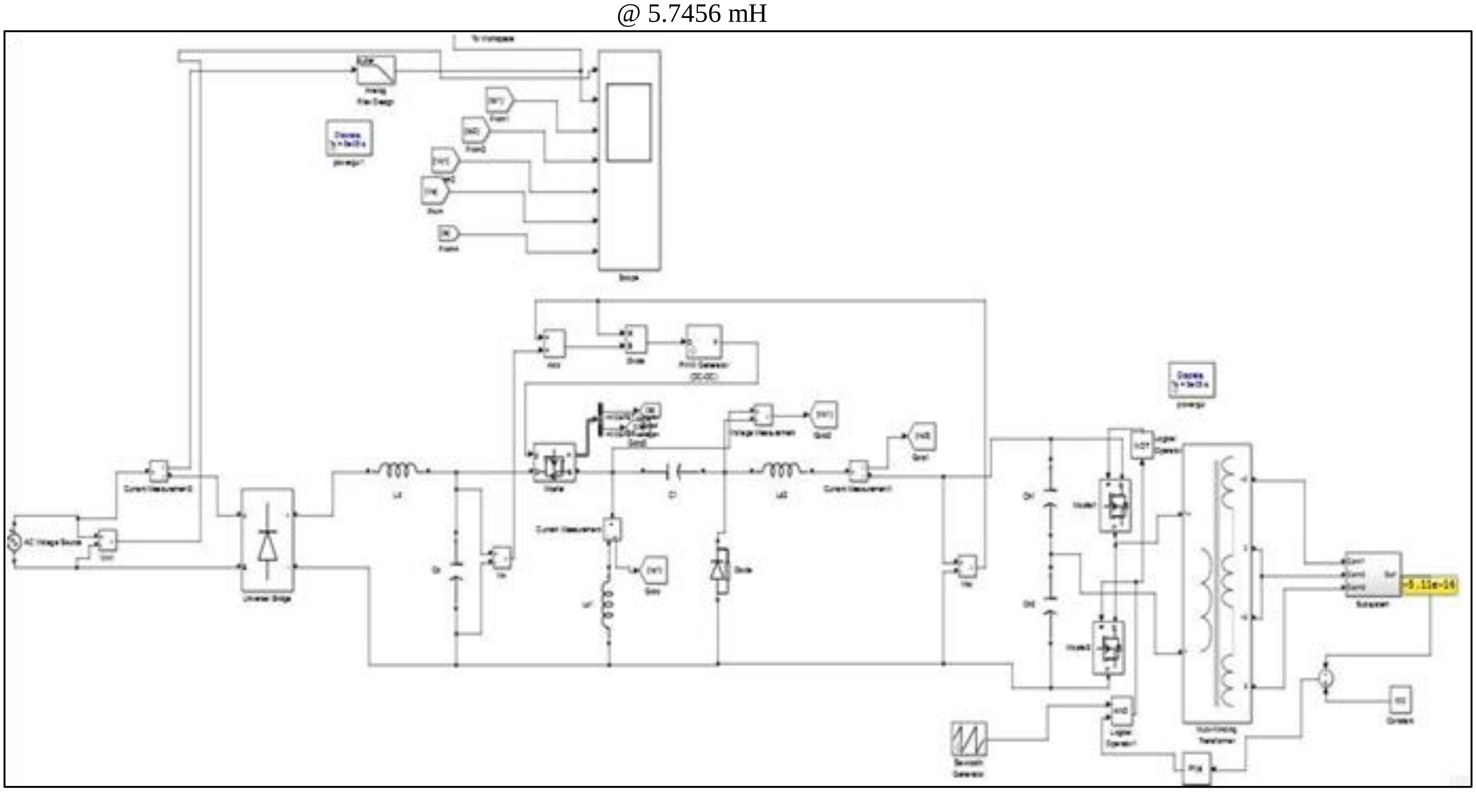


Fig. 5: Modeling of Zigzag converter in MATLAB/Simulink

V. COMPONENTS SPECIFICATION

Sr. No	C DCM	V
1	Input inductor L_1	0.@2 Mh
2	Capacitor C	1@.@24 nF
3	Output inductor L_2	1.160 mH
4	Filter capacitor C_f	330 nF
5	Filter inductor L_f	3.0 mH

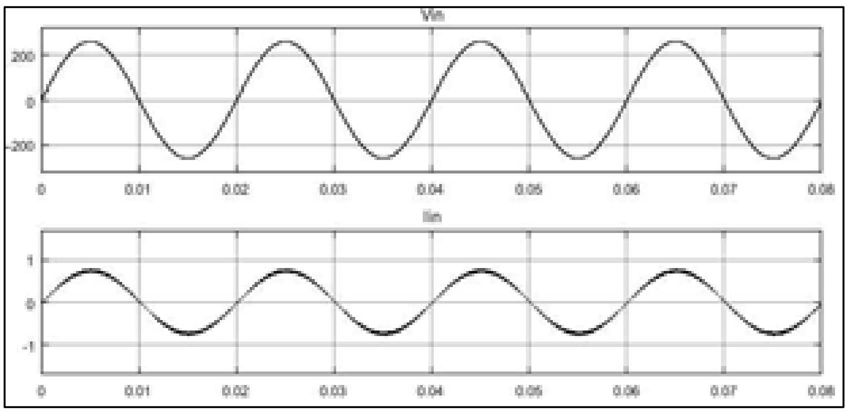
Table 1

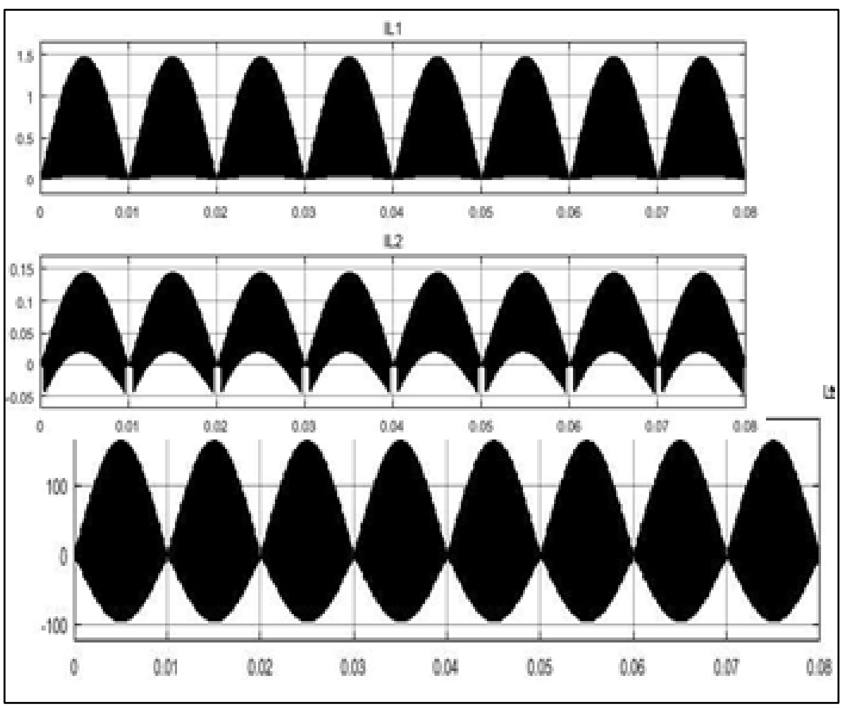
Sr. No.	C CCM	V
1	Input inductor L_1	4.603 mH
2	Capacitor C	0.0627 nF
3	Output inductor L_2	5.7465 mH
4	Filter capacitor C_f	330 nF
5	Filter inductor L_f	3.0 mH

Table 2

VI. SIMULATION RESULTS OF ZIGZAG CONVERTER

A L1 of Zigzag converter is in discontinuous conduction





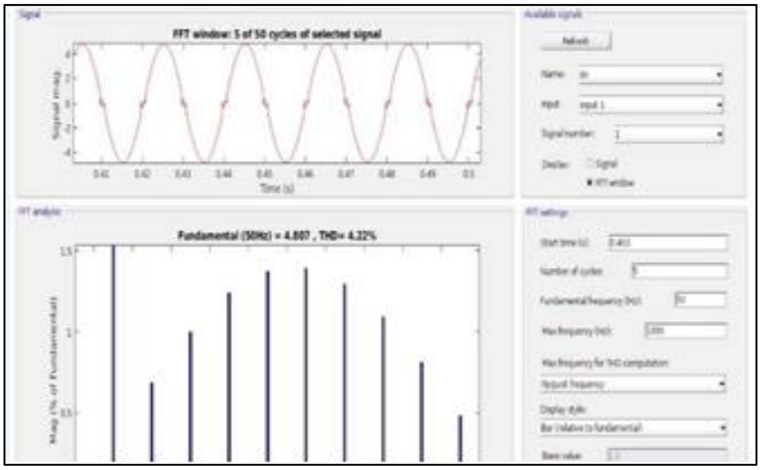
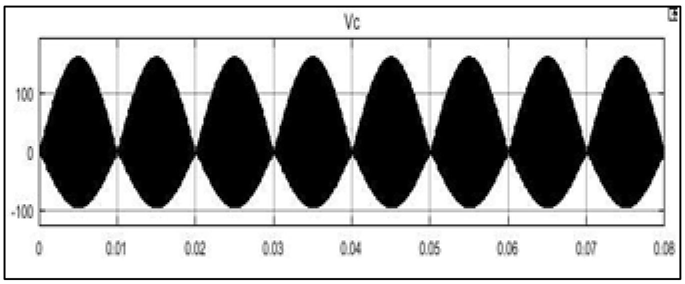
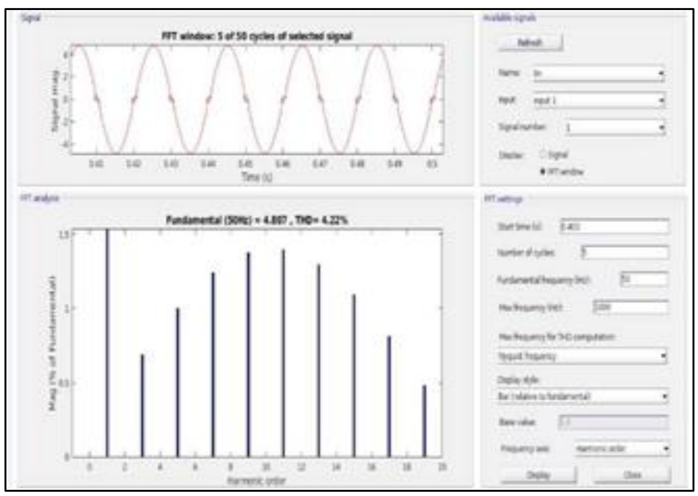
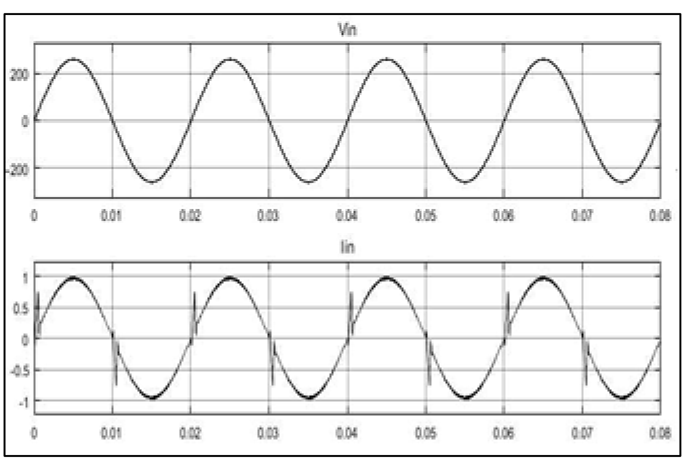


Fig. 6: output waveform of components Zigzag converter with L1 is in DCM with its harmonic spectrum

C of Zigzag converter is in discontinuous conduction







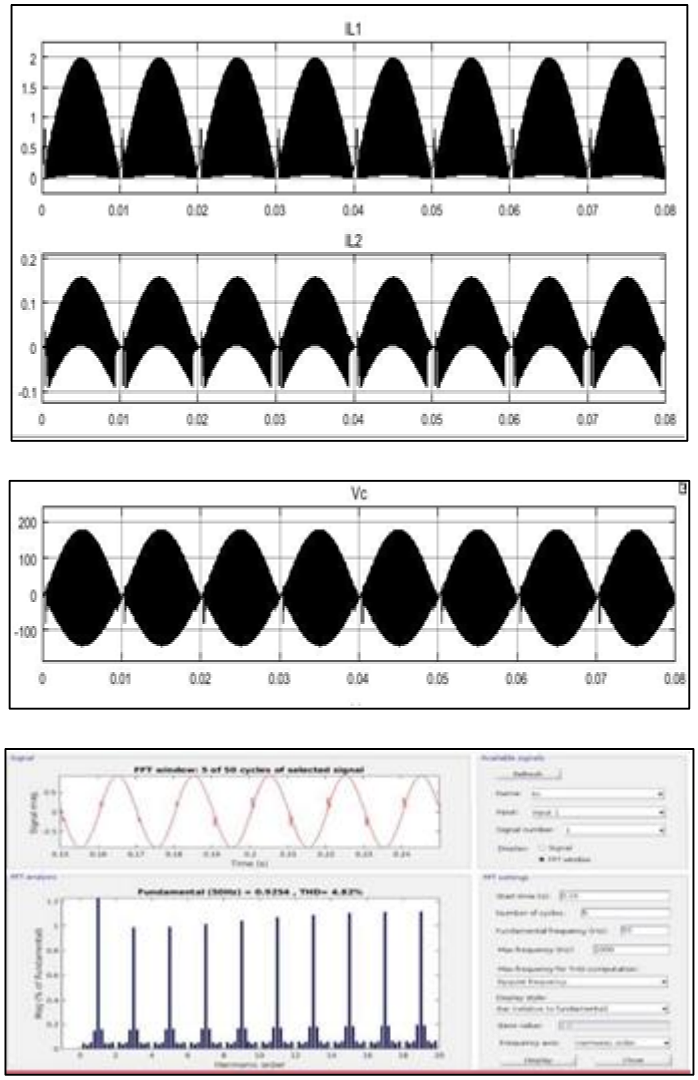
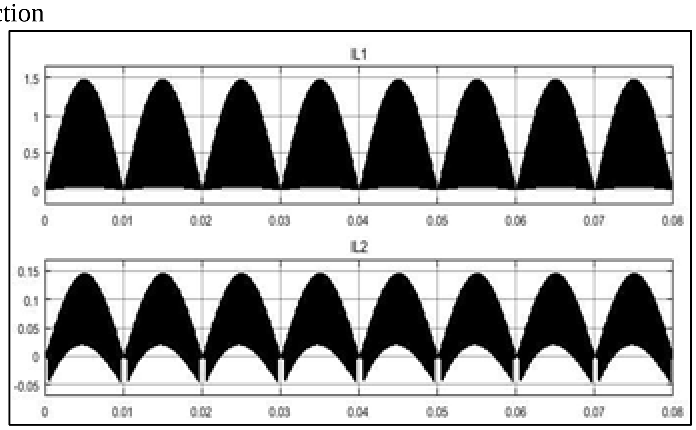


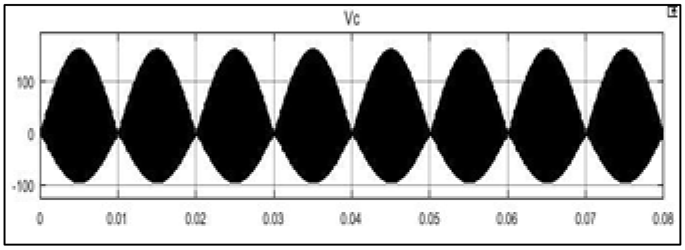
Fig. 7: Output waveform of components Zigzag converter with C1 is in DCM with its harmonic spectrum

C L2 is in discontinuous conduction



VII. CONCLUSION

The operation of Zigzag converter in DCM for switch mode power supply has been proposed. The performance of Zigzag converter for its components operating in discontinuous conduction has been analyzed. Among them output inductor in DCM gives good performance to the application with reduced total harmonic distortions (THD) (less than 5%) and regulated dc output voltage with wide variations in input operating voltage. The performance of Zigzag converter is evaluated in MATLAB/Simulink.



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