ANALYSIS OF SINGLE-STAGE HIGH-FREQUENCY RESONANT AC/AC CONVERTER USING ARTIFICIAL NEURAL NETWORKS

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Abstract: In large applications like LCD panel back lighting, street lighting, lighting of tunnel etc LED driver is used because of its three major functions such as power factor corrections, constant current output and galvanic isolation. A single stage high frequency AC-AC converter using soft computing techniques are proposed in this paper. It is composed of LCL-T resonant rectifiers which act as an output. The main operation focussed in this paper is converting AC input voltage into a high frequency output voltage which is sinusoidal. Initially three stages of LED driver is presented followed by its topology derivation and its operating principle. Then its performance is analysed using soft computing technique such as neuro network.

Index Terms – AC-AC converter, LED Driver, LCL-T rectifier, zero voltage switching

I. INTRODUCTION

Light Emitting diode (LED) has now become common in our daily lives because of its high efficiency in luminous and its long life. They are mainly used in applications where power consumption and maintenance of systems are get greatly reduced. The input power requires by LED street lamps is between 60W to 240W. Hence these LED drivers requires Power factor correction to meet high power factor. In LED driver, LED strings are connected in parallel to have enough luminance. Generally, in LED strings current sharing ability will be poor because of its negative temperature coefficient and its voltage-current characteristics.[1][2] To overcome this problem, current balancing technique is used. Also for safety purpose, galvanic isolation is used.

A block diagram of three stage multichannel constant current source is shown in Fig 1[3].

In PFC stage, high power factor is analysed. Then the AC voltage gets converted into DC voltage which is stable. The obtained output from AC-DC converter is now converted into low output DC voltage so that low frequency voltage ripple in previous stage is reduced. The last stage of LED driver is constant current. Here constant current is achieved in LED strings and current balancing is done[4]. Galvanic isolation is provided by isolation transformer in the second stage. Although the performance of three stage constant current DC-AC converter is good, it carries the disadvantage of lower efficiency and complex circuit.

To overcome above disadvantages and to have better efficiency, two stage constant current AC-DC LED driver is proposed. The block diagram of two stage AC-DC LED driver is shown in Fig 2. A two stage constant current AC-DC LED driver is obtained by integrating DC-DC stage and constant current source. This multichannel constant current source is constructed by Asymmetrical Half Bridges (AHB) as LED strings. These AHB’s undergoes galvanic isolation and these LED Strings are supplied with constant current by regulating the supply of AHB’s. This structure is further complicated and cost is high since AHB’s are used. These AHB’s have separate power module and controller. A two stage constant current AC-DC LED driver is proposed with LCL-T resonant converter consists of multi transformer and voltage doubler. The block diagram is shown in Fig 3.
amplitude of input sinusoidal voltage to constant current and it also matches the frequency with resonant frequency of LCL-T resonant rectifier. This high frequency resonant AC-AC converter converts input ac voltage to high frequency ac voltage which is sinusoidal in nature. The output amplitude and frequency is constant and it implements power factor correction and galvanic isolation. These resonant passive LCL rectifier gives constant current output so that the frequency of input voltage is equal to resonant frequency of LCL-T network. The major advantage of this structure is modular and quite cheap compared with others. To build a LCL-T resonant rectifier eight passive components are required to achieve constant current output. The major disadvantage of output channel of output current is not regulated in a closed loop hence its accuracy gets affected by its passive components. This paper mainly focuses on high frequency resonant ac-ac converter.

Two stage high frequency resonant ac-dc converter composed of two power conversion units which are connected in cascaded that includes PFC unit i.e high frequency resonant ac-ac converter and high frequency ac-dc converter. If these two units have separate power module and controller then it is named as two stage high frequency resonant ac-ac converter. This structure can be used for high power applications since it has high performance output, large components and high cost. Single stage resonant ac-ac converter is preferred for low or medium power applications like LED driver because components are less and cost is less. In single stage, one power conversion unit is used by sharing the switches and one controller is used. In this paper it is mainly focused on integrating two main units into one unit i.e high frequency resonant ac-dc converter and PFC unit[5].

II. TOPOLOGY DERIVATION

The main purpose of deriving topology for single stage high frequency resonant ac-ac converter is the same as single stage PFC ac-dc unit. Here the boost converter is used as a PFC unit which operates in discontinuous inductor current mode (DCM) can gain high power factor when it has constant duty cycle. An APWM LCLC series - parallel resonant inverter is used as a high frequency resonant dc-ac converter. It has the advantage of producing sinusoidal output voltage with low THD and Zero Voltage Switching (ZVS). The proposed method is to integrate boost and APWM LCLC series-parallel resonant inverter into a single unit in the following Fig 4.

Fig 4 Topology derivation of the single-stage high frequency resonant ac-ac converter

The first stage is boost converter which is composed of components such as $C_d$ dc Link Capacitor, $D_b$ Diode, $I_b$ Boost Inductor and $S_p$ Power Switch. An APWM LCLC series-parallel resonant inverter composed of Transformer $T_R$, load resistance $R_L$, two power switches $S_R$ and $S_F$, second harmonic trap $L_2$ and $C_2$, LCLC series parallel resonant tank. This LCLC series parallel resonant tank includes series branch and parallel branch. In series branch, inductor $L_3$ and capacitor $C_3$ are present which is turned on when it achieves maximum power transfer and Zero voltage switching during operating frequency. In parallel branch, $L_p$ and $C_p$ are present to provide inductive impedance during operating frequency. Second harmonic trap is used to reduce second harmonic component in its output voltage. To integrate PFC unit and APWM LCLC series parallel resonant inverter, switches $S_R$ and $S_F$ are turned on or off simultaneously. Switches $S_R$ and $S_F$ are operated complimentarily. During the duty cycle of switch $S_R$ at 0.5 in APWM LCLC series parallel resonant inverter, switches $S_R$ and $S_F$ are turned. When node A and node B are connected all in one, switches $S_R$ and $S_F$ are turned on. The diode $D_b$ is forced to conduct when the switches $S_R$ and $S_F$ are turned off. At the same time $S_F$ is turned. Hence node A and node B are connected all in one. $S_R$ and $S_F$ are connected in parallel so that the voltage between node A and node B is zero and any one of the switch can be removed. Now the diode $D_b$ and switch $S_R$ is connected in parallel and the current through the switch $S_R$ is bidirectional. Hence diode $D_b$ is removed. Since it is an integrated circuit, the 2 switches $S_R$ and $S_F$ are shared by power factor correction unit and high frequency resonant ac-dc unit. Here only one controller is used which is needed to control the output voltage amplitude. This proposed structure is simple and less cost. The only disadvantage of this structure is the construction of LCLC series parallel resonant tank and second harmonic trap. One of the major crisis in implementing single stage PFC ac-dc unit is dc link voltage which varies input voltage amplitude and load. Hence the proposed single stage high frequency ac-ac unit is designed. The input power factor can be deduced as

$$PF = \frac{P_{in}}{U_{in}I_{in}} = B\sqrt{\frac{2}{\pi A}}$$

Where,

$$A = \int\frac{m|\sin\omega t|}{1 - m|\sin\omega t|}d\omega t$$

$$B = \int\frac{|\sin\omega t|}{1 - m|\sin\omega t|}d\omega t$$

Where $U_{in}$ is the RMS value of input line voltage[7]. Quality factor for series and parallel resonant network $Q_s$ and $Q_p$

$$Q_s = \frac{\omega_{sw} L}{R_{eq}}$$

$$Q_p = \frac{R_{eq}}{\omega_{sw} L_p}$$

$$\omega_{sw} = \frac{1}{\sqrt{L_p C_p}}$$

$$R_{eq} = N^2 R_L$$

III. PRINCIPLE OF OPERATION
The principle of operation of proposed single stage high frequency resonant ac-ac converter is explained by following waveform in Fig. 5.

**Mode I:** Here the time limits from $t_0 \leq t \leq t_1$. At the time of $t_0$, SF is gated on when it is in zero voltage and diode DB is forced to conduct previously. In this mode the inductor current ILB increased constantly and also the stored energy in resonant tank supplies power to the load by freewheeling through switch SF.

**Mode II:** In this the time limits from $t_1 \leq t \leq t_2$. At the time of $t_1$, SF is turned off simultaneously CF gets charged and CR is discharged. USf is increased and the capacitors CF and CR gets limited then at ZVS, SF is turned off. Hence turn off losses gets reduced. This mode reaches its end when uSr falls to zero.

**Mode III:** Here the time limits from $t_2 \leq t \leq t_3$. At time $t_2$, uSr falls to zero completely and diode DR starts conduction. Uin discharges LB and the stored energy releases to resonant tank and capacitor CB.

**Mode IV:** In this the time limits from $t_3 \leq t \leq t_4$. At $t_3$, the switch SR is turned on at ZVS because the diode DR makes USr to zero. The circuit of this mode is same as that of mode III.

**Mode V:** Here the time limits from $t_4 \leq t \leq t_5$. At time $t_4$, diodes DR1 and DR2 are reverse biased when inductor current ILB reaches zero. The stored energy in capacitor CB released to resonant tank and its supplies to load continuously.

**Mode VI:** The time period limits from $t_5 \leq t \leq t_6$. During the time $t_5$, SR is gated off at zero voltage switching so that the turn off losses are reduced. At the same time uSr gets limited by the capacitors CF and CR.

**Mode VII:** In this the time limits from $t_6 \leq t \leq t_7$. At $t_6$, diode DF is ready to conduct and uSr falls to zero at zero voltage switching condition which turns on SF. during this mode two diodes DR1 and DR2 is turned on. At $t_7$, converter begins its new switching cycle by turning on SF at ZVS. The operating modes from mode I-VII gives positive cycle output voltage. For negative cycle also same operation is repeated.

Assumptions are made for analysing the performance of single stage high frequency resonant ac-ac converter.

- a) the inductor LB is constructed to operate only in discontinuous inductor current mode.
- b) to eliminate the ripple in dc link voltage, large dc link capacitor CB is designed.
- c) during switching period, ac line voltage is consider as a constant value so that the operating frequency of the switches SR and SF is much more higher than ac input line voltage
- d) assume that the efficiency of the converter is equal to one and hence the losses are completely neglected[8],[11]-[14].

IV. SIMULATION RESULTS AND DISCUSSION

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**A. RESONANT AC-AC CONVERTER WITH FUZZY LOGIC**

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**Fig 6 Simulation diagram of single stage high frequency resonant ac-ac converter with fuzzy logic**

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**Fig 7. Fuzzy Sets and Output States**

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**Fig 8. Fuzzy Rule base viewer**

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**Fig 9. Simulation response of Input Current With Fuzzy Logic**

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**Fig 10. Simulation response of DC Link Voltage With Fuzzy Logic**

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**Fig 11. Simulation response of Output Voltage With Fuzzy Logic**

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For controlling process neural network is used in the proposed work. In this neural structure the load voltage is compared with reference voltage and the error signal is given to neural network. Thus the control signal is produced. It has less number of error to gain high performance. The signal generated from the pulse generator is then compared with control signal and gate pulses are produced. Fig. 13 shows ADALINE neuro model of neural network model and Eqns 9, 10 shows Target value and weight updatation model 

\[ Y = \sum_{j=1}^{n} w_j i_j \]  
\[ w(j+1) = w(j) + \alpha e(n)i(n) \]

where \( Y \) is the amplitude of the desired source current, \( \alpha \) is learning rate, \( e(n) \) is error between output equation and target value, \( i(n) \) is input values and \( w(j) \) is weights of the ADALINE network[15].

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Parameters</th>
<th>Rise time (tr)</th>
<th>Peak time (tp)</th>
<th>Peak overshoot (mp)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Load Voltage</td>
<td>251.78</td>
<td>175.34</td>
<td>94.30</td>
</tr>
<tr>
<td></td>
<td>Load Current</td>
<td>251.78</td>
<td>175.34</td>
<td>94.30</td>
</tr>
</tbody>
</table>

Fig 17. Output voltage waveform using neural network

V. CONCLUSION

In this paper, the proposed work of implementing soft computing techniques in single stage high frequency resonant ac-ac converter is analysed completely. Also the three stages of ac-ac converter using LED driver is discussed. The proposed neural network provides controlling process hence efficiency is high. In the existing system, single stage high frequency resonant ac-ac converter is not used for high power applications. By using neural and fuzzy network high frequency ac-ac converter will be use for high power applications because of its controlling techniques. Also, in future optimisation technique can be implemented to have better performance.

REFERENCES


