LCC RESONANT CONVERTER FOR X-RAY GENERATOR

Bhuvaneswari. C 1 , Dr. Samuel Rajesh Babu. 2
Associate Professor 1
Department of Electrical
and Electronics Engineering,
Sathyabama Institute of
Science and Technology,
Chennai-600119, TamilNadu
Bhuns@ekar@yahoo.co.in

June 25, 2018

Abstract

A LCC Resonant converter has been designed for a X-Ray Generator. The Converter is simulated to obtain a output voltage of 15KV a input voltage of 540V. The transfer function is derived for the system. The Magnitude values and Phase angles are plotted using Matlab. The Gain Margin and Phase Margin is verified to be infinity as that of a second order system. So the system will have the properties of second order System. The Second order Systems will not have Oscillations and so the settling time will be very less.

Keywords: Resonant Converter, LCC Converter, X-Ray Generator, High Voltage Generator

1 INTRODUCTION

High Voltages Generation with less cost is becoming the need of the hour. The high voltages are linked with the smart grid and
power consumption and utilization are monitored. High voltages
have many medical applications in X-Rays like Fluoroscopy and
Radioscopy. Fluoroscopy involves Low Power levels and
Radioscopy involves Higher power Levels. The DC input Voltage
should be in the range of 400 to 750v for a high voltage
application. Resonant Converters have many advantages. Of
many types of Resonant Converters, Hybrid Resonant Converters
combine the advantages of both Series and Parallel Converters.
The Capacitive filter at the output side proves more suitable for
high voltage applications[1-4]. The Resonant Converter designed is
useful for a high frequency corona generator [5]. The output
Voltage is regulated for a wider range using Topology- Morphing
control [6]. Many Controllers are used for measuring the
Performance of the output voltage [7]. Resonant Converter can
operate in both Continuous and discontinuous mode. For a high
frequency and High Voltage application, the converter should be
operated in Discontinuous mode for better performance [8]. So for
X-Ray generators, LCC Resonant Converters have been identified
to be more suitable. This Paper comprises of an Introduction
section, X-Ray Generators section, Simulation of Resonant
Converters section, Results and Discussion section and the
Conclusion.

2 X-RAY GENERATORS

X-Rays are electromagnetic Rays with energies in the range of 100ev
to 100Kev. These rays are highly used in Medical applications.
Other than the Medical Industry, they also have wide applications
in fields like Fault detection in Electrical, Electronic and Mechanical
Components. Abnormalities in the seeds which is very much helpful
for the agricultural Industry. Also it is used in the detection of Food
Adulteration. The main elements of the X-Ray Generator are the
high voltage generator and its cooling systems.
3 SIMULATION OF RESONANT CONVERTER

The fig 1 represents the LCC Resonant Converter. The Converter constitutes of an Inductor $L_S$ and a Capacitor $C_S$ connected in Series and a Capacitor $C_p$ connected in Parallel. An input voltage of 540V is given as input to generate 15KV as output voltage. The Frequency response of the LCC Resonant Converter combines the advantages of Series and Parallel Resonant Converter. The specifications of LCC Resonant Converter simulated using matlab are mentioned in Table 1.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>540V</td>
</tr>
<tr>
<td>Series Capacitor $C_S$</td>
<td>1.4 microfarad</td>
</tr>
<tr>
<td>Series Inductance $L_S$</td>
<td>42 microhenry</td>
</tr>
<tr>
<td>Parallel capacitor $C_p$</td>
<td>120 nanofarad</td>
</tr>
<tr>
<td>Transformer Turns Ratio</td>
<td>1:24</td>
</tr>
<tr>
<td>Output Filter</td>
<td>5.5 microfarad</td>
</tr>
</tbody>
</table>

A dc input voltage of 540 voltage is given to the converter. With this input voltage, 15 KV Output voltage is generated. The
waveforms for the input voltage, input current, output voltage and output current has been given in the fig 2. The Waveform obtained for both output voltage and output current is smooth and free of ripples because of the capacitor filter at the output side. The output voltage rises from zero and attains maximum after sometime. After reaching maximum, the voltage remains at a constant value of 15 Kilovolts. The output current also starts to rise and after reaching a peak value of 969 milliamps maintains the same as a constant value. The peak value of the output current and output voltage settles at a minimum time making the settling time very less.

Fig 2. Waveform of Input Voltage, Input Current, Output Voltage and Output Current

The MOSFET’s M1 and M3 conduct for the positive cycle and M2 and M4 Conduct for the negative half cycle. The Pulse P1 supplies MOSFET’S M1, M3 and the Pulse P2 supplies MOSFETS M2 and M4. The gate pulses are generated by the pulse generator. The Pulses P1 and P2 are generated alternately so that the diagonally connected MOSFET’s namely M1, M3 and M2, M4 are turned on and off alternately. The generated gate pulses P1 and P2 are shown in the fig 3

International Journal of Pure and Applied Mathematics Special Issue
The High voltage Transformer is used to step up the voltage. The Turns ratio of the Transformer is 1:24. The Waveforms of the Primary and Secondary winding are shown in the fig 4. Around 20KV voltage is generated at the Secondary winding of the transformer. The Primary voltage of the transformer can be stepped to a higher level depending upon the transformer turns ratio. But when it is stepped up to a higher voltage the losses of the transformer also increases. So considering the losses to be minimum, a turns ratio of 1:24 has been selected by trial and error procedure.

The power and the efficiency is also calculated for the system. The output power is obtained to be 15KW. The input Power,
output power and Efficiency are shown in the fig 5. The output power increases from zero and settles at a maximum of 15kilotons at a later stage than the voltage. The efficiency of the proposed converter settles down at 83.91% which proves that the losses are less and so can be employed for a X-Ray Generator.

![Fig 5. Waveforms of Input Power, Output Power and Efficiency](image)

The Values of the parameter obtained after simulation is tabulated in Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage(Kilo Volts)</td>
<td>14.84</td>
</tr>
<tr>
<td>Output Current(milliamps)</td>
<td>969</td>
</tr>
<tr>
<td>Voltage at the Primary Winding of Transformer(Volts)</td>
<td>600</td>
</tr>
<tr>
<td>Voltage at the Secondary Winding of Transformer(Volts)</td>
<td>15</td>
</tr>
<tr>
<td>Output Power(Kilo Watts)</td>
<td>14.93</td>
</tr>
<tr>
<td>Efficiency(Percentage)</td>
<td>83.91</td>
</tr>
</tbody>
</table>

4 RESULTS DISCUSSION

The Equivalent Circuit of the Converter modelled is represented in Fig 6.
Fig 6. Equivalent Circuit of Proposed Converter

The impedances $Z_1$, $Z_2$ and $Z_3$ are the Impedances with Inductor or the capacitor. Stability of the proposed converter can be analyzed by determining the transfer function. The LCC Resonant Converter Transfer Function is given by

$$\frac{V_o(s)}{V_{in}(s)} = \frac{Z_3}{Z_1+Z_2} = \frac{C_1}{s^2LC_1C_2+C_2}$$

The Obtained transfer function is compared with the standard form of second order system. The damping Ratio (defined as ratio of actual damping to critical damping) is found to be zero and so the system is classified in undamped system. The response of the second order undamped system does not have any oscillations and hence the system settles down very fast.
The transfer function can be analyzed in frequency domain using Bode Plot, Nyquist Plot, Polar Plot and M and N Circles. Bode Plot of the converter is graph of Frequency with Magnitude and Phase. The Bode Plot for the converter is obtained for the transfer function in the figure 7. The Magnitude and Phase plot are done using Matlab coding. With the magnitude and the phase plot, the Gain margin and phase Margin of the system is calculated. Both are found to be infinity which proves the system is a Second Order system.

5 CONCLUSION

Resonant Converter for X-ray has been designed. The circuit has been simulated and the output voltage, Power and Efficiency has been obtained. Transfer Function is obtained for the system. The Bode plot of the undamped second order system is drawn which proves the settling time will be very less.
References


Twenty-Fourth Annual IEEE.