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Supply Power Factor Improvement in Ozone Generator System Using Active Power Factor Correction Converter

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ABSTRACT

Artificial Ozone Generating system needs High Voltage, High Frequency supply. The Ozonator distorts the supply currents and henceforth affect the supply power factor. This paper presents the performance comparison of PWM inverter to Power Factor Corrected (PFC) converter with PWM inverter based High-voltage High-frequency power supply for ozone generator system. The conventional inverter has front end bridge rectifier with smoothing capacitor. It draws non-sinusoidal current from ac mains; as a result input supply has more harmonics and poor power factor. Hence, there is a continuous need for power factor improvement and reduction of line current harmonics. The proposed system has active power factor correction converter which is used to achieve sinusoidal current and improve the supply power factor. The active PFC converter with PWM inverter fed ozone generator generates more ozone output compared to the conventional inverter. Thus the proposed system has less current harmonics and better input power factor compared to the conventional system. The performance of the both inverters are compared and analyzed with the help of simulation results presented in this paper.

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1. INTRODUCTION

Ozone has an extraordinarily large microbicidal efficiency spectrum. Applied correctly, it has a very quick and efficient effect on almost all known bacteria, viruses and other microorganisms. Moreover, Ozone degrades to Oxygen and does not leave any by-products. Thus it is a highly efficient and environmentally friendly means of water disinfection, but also for removing Iron or Manganese traces from drinking water. Typical application areas are: Water treatment in swimming pools, drinking water or cooling water treatment, water treatment in beverage industries or zoo pools and aquari**a.** It does not generate any residues and harmful byproducts during process. It is used in paper manufacturing mill, cement mills and food processing industries. The ozone is generated both naturally and artificially. Natural method generates low level ozone concentration, so it cannot be used for industrial purpose. Artificially it can be generated in many ways such as Corona Discharge, Electrolysis and Radiochemical method. Corona discharge method creates higher quantities of ozone more efficiently. Corona cell life exceeds the life expectancy of any Ultra Violet (UV) bulb when dry air or oxygen is used. Corona discharge method is more cost-effective than UV-ozone generation for large scale high concentration installations. And much less electrical energy is required to produce the same quantity of ozone [1-3]. Therefore Corona discharge method for generating ozone is considered in the present work.

In Corona discharge method, the oxygen is supplied through two plates in the presence of high voltage. As a result, ozone is generated. The high voltage is generated by different methods [4-5]. High voltage is generated from line voltage of 230 V, 50Hz using step up transformer. But in this method large size transformer is required to convert low voltage ac to high voltage ac due to line frequency and also has less safety and efficiency [4]. High voltage is generated from low voltage dc to high voltage ac using power converter or Radio Frequency Oscillator. The use of power converters offers adaptability over wide range due to ease of control using analog/digital controllers. Converters operated at high frequency will also help in the reduction of large volume of magnetic components required [5]. Current fed push-pull inverter based ozone generator system developed in [6] has high voltage conversion ratio but at the cost of more conduction losses and reduced efficiency. The foresaid problem can be addressed using soft switched high frequency high voltage supply.

The use of high frequency power supplies increases the power density applied to the ozonizer electrode surface which in turn enhances the ozone production for a given surface area, with reduced peak voltage requirement [7]. By increasing the operating frequency the ozone production can easily be controlled [8]. Many compact converter topologies have been proposed in order to improve efficiency [6- 8] of the Ozonator. Some power supply derived from ac main supply. In this case the front end has uncontrolled rectifier with a large DC link capacitor. This rectifier is widely used because of its simplicity and robustness but with the distorted line currents. As a result, the input power factor is poor [10].Various PFC techniques are employed in converters to overcome these power quality problems [11-16] out of which the basic boost converter topology has been extensively used in various power supply conversion applications. Implementing power factor correction (PFC) into low frequency to high frequency power supplies will maximize the power handling capability of the power supply and current handling capacities of power distribution networks. A fuzzy controller based PFC for boost converter was proposed in [15] to improve the dynamic performance and reduce the steady stae error.

The low frequency to high frequency high voltage power supply system has more input current distortion and poor power factor. It affects the system performance and life time. These harmonics can be reduced by active PFC converter. The PFC converter is used to improve the input power factor, reduce cable and device rating and reduce the current harmonics. This paper proposes PFC high voltage high frequency power supply for Ozonator.

2. POWER FACTOR OF VARIOUS LOADS

Power factor is a measure of the displacement between the input voltage and current waveforms to an electrical load that is powered from an AC source.

2.1 Power Factor of a Linear Load

The linear loads like lamp, cooking stoves draw sinusoidal currents. The voltage and current waveforms for a linear load are shown in Figure 1.

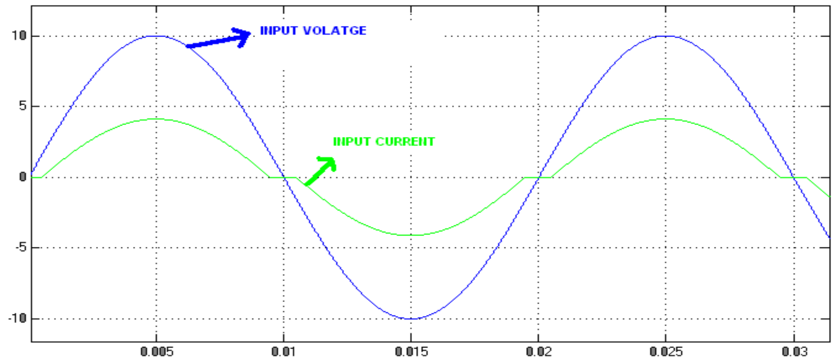

Figure 1. Ac input voltage and current waveform for linear load

2.2 Power Factor of a Non Linear load

A non-linear load on a power system is typically a rectifier, fluorescent lamp, welding machine etc. These loads draw the non-sinusoidal current. This current also has more distortion and the supply power factor is poor. Figure 2 shows the relation between current and voltage for non linear load.
For sinusoidal voltage and non- sinusoidal current the input power factor can be expressed as

$$PF = \frac{V_{rms} I_{1rms} \cos\phi}{V_{rms} I_{rms}} = K_p \cos\phi \quad (1)$$

Where $K_p = \frac{I_{1rms}}{I_{rms}}$ and K_p range is [0, 1]
$\cos\phi$ is the displacement factor of the voltage and current. K_p is the purity factor or the distortion factor.

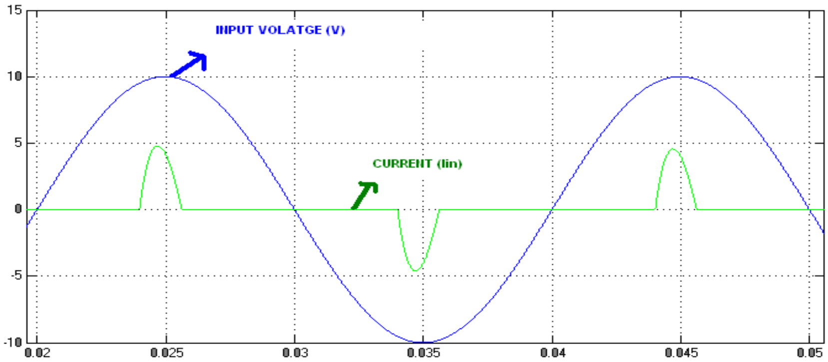

Figure 2. Ac input voltage and current waveform for non linear load

Another important parameter that measures the percentage of distortion is known as the current THD which is defined as follows:

$$K_p = \frac{1}{\sqrt{1+THD_i^2}} \quad (2)$$

Where

$$THD_i = \frac{\sqrt{\sum_{n=1}^{\infty} I_{hrms}^2}}{I_{1rms}} \quad (3)$$

Conventional AC to DC conversion is a very inefficient process, resulting in waveform distortion of the current drawn from the ac main supply. At higher power levels severe interference with other electrical and electronic equipment may become apparent since harmonics are injected to the power utility line. Another problem is that the power utility line cabling, the installation and the distribution transformer, must all be designed to withstand these peak current values resulting in higher electricity costs for any electricity utility company. This problem can be addresses using power factor correctors. Power factor correctors are of two types viz. Passive and Active. The passive PFC are made of passive components and are normally bulky and operate at power frequency. Active PFC offers better THD and is significantly smaller and lighter than a passive PFC circuit. To reduce the size and cost of passive filter elements, an active PFC operates at a higher switching frequency. The Active PFC shapes the input current and there will be feedback control to regulate the output voltage. Buck, boost, fly back and other converter topologies are used in active PFC circuits. The basic boost converter topology has been extensively used in various power supply conversion applications. Therefore a boost converter is used along with the inverter as a supply unit for an Ozonator.

3. POWER SUPPLY SYSTEM FOR OZONATOR

A normal PWM inverter was used so far as power supply converter for Ozonator. The proposed ozone generating system is shown in Figure 1. It consists of single phase AC supply, bridge rectifier, PFC converter, high-frequency PWM inverter using power IGBTs, high-frequency transformer and an electrode tube. High frequency PWM inverter operation is explained in detailed in [17-18]. The boost converter is used to control the input current and improve the power factor. As a result the overall system performance is improved and rating of the device is reduced. The output voltage of the inverter is stepped up to above 5-6 kV (peak value) using High frequency High voltage transformer and then is fed to the electrodes for ionizing the gas. The UU-80 ferrite core is used. The required frequency of currents is 6 kHz.

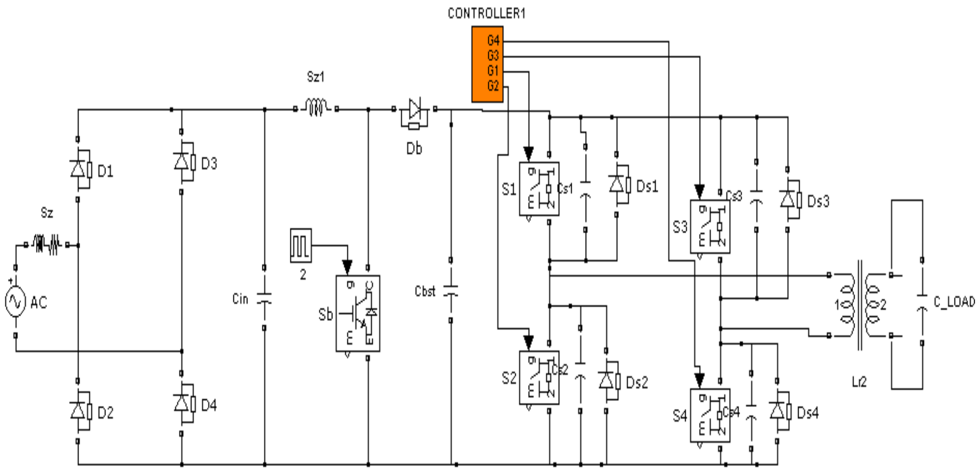

Figure 3. Proposed system for ozone generator

4. SIMULATION RESULTS

The simulation is carried out in Matlab/Simulink environment. The conventional circuit which was used to supply power for Ozonator without PFC is shown in Figure 4. It consists of ac source, a rectifier, a smoothing capacitor, high frequency inverter, high frequency transformer and electrodes.

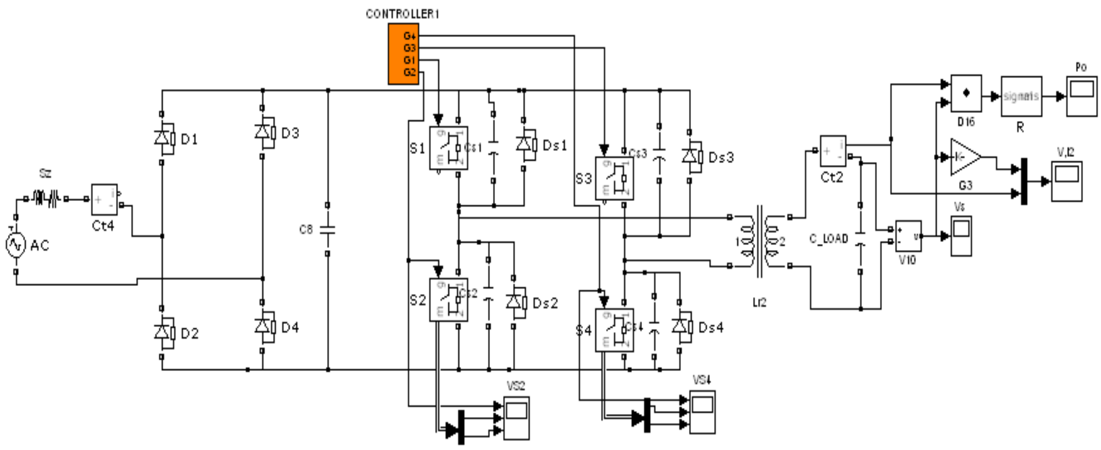

Figure 4. Conventional Power Supply Circuit for Ozonator without PFC

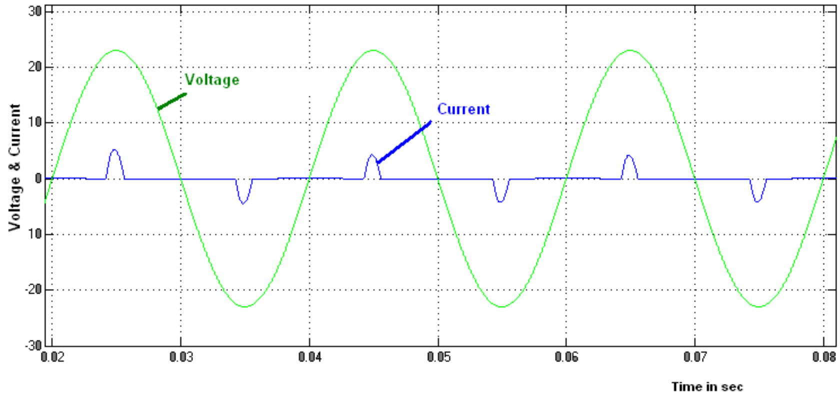

Figure 5. Input Voltage and Current (Scale Volt One Unit=10v)

The input ac supply voltage and current waveform as shown in Figure 5. The switching pulses, current through the switches and voltage across the switches are shown in Figure 6 and Figure 7 for switches S2, S3 and S1, S4 respectively. Figure 8 shows the transformer primary and secondary currents. These currents are distorted. Figure 9 shows the transformer secondary side voltage and current wave form. The FFT spectrum of the output current is shown in Figure 10.

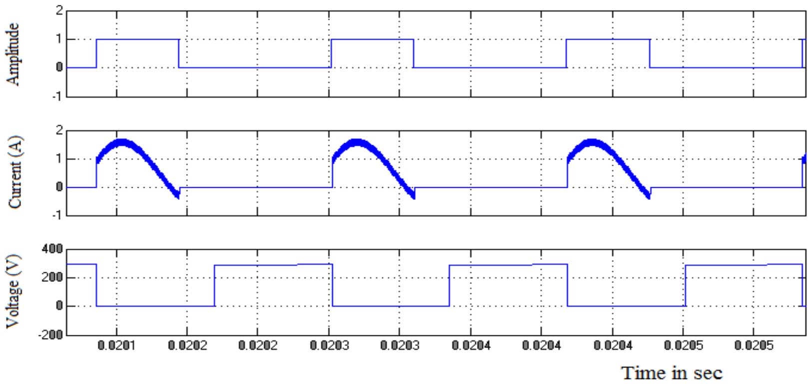

Figure 6. Switching Pulse, Current Through and Voltage across the Switch S2 and S3

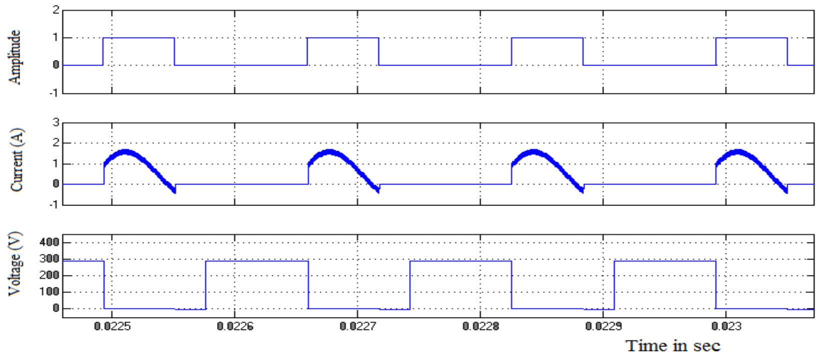

Figure 7. Switching Pulse, Current Through and Voltage across the Switch S1 and S4

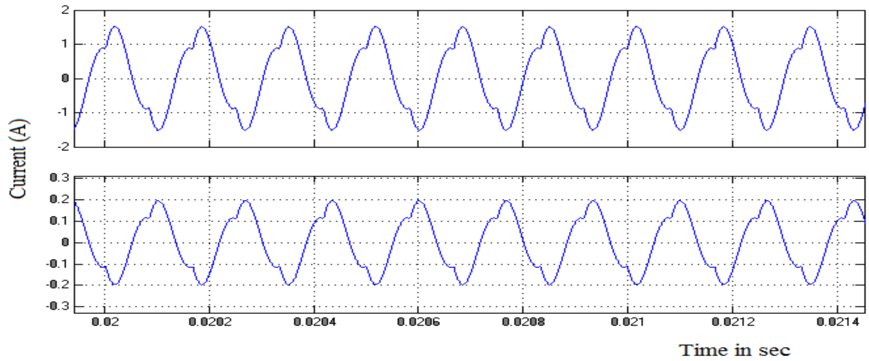

Figure 8. Transformer Primary and Secondary Currents

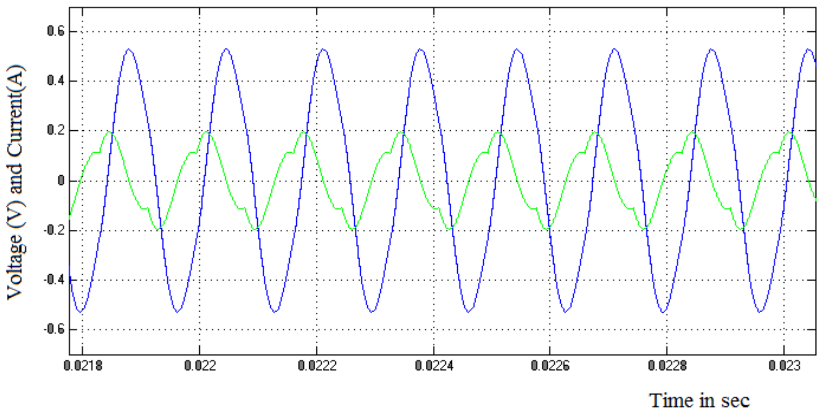

Figure 9. Transformer Secondary Side Voltage and Current

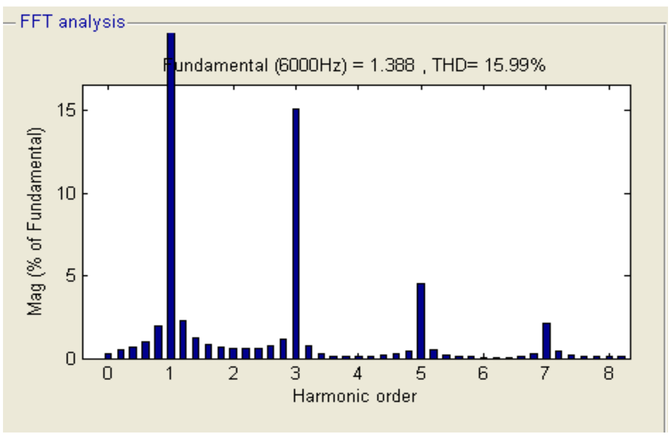

Figure 10. FFT Spectrum of the Output Current

As observed from the simulated waveforms input current is discontinuous and the supply power factor is poor. Therefore a active power factor correction converter based PWM inverter is proposed. The simulation circuit of proposed configuration is shown in Figure 11. It has ac source, rectifier and boost converter, smoothing capacitor, high frequency PWM inverter, high frequency transformer and electrodes. The input ac supply voltage and current waveform as shown in Figure 12. The switching pulses, current through the switches and voltage across the switches are shown in Figure 13 and Figure 14 for switches S2, S3 and S1, S4 respectively. Figure 15 shows the transformer primary and secondary currents. Figure 16 shows the transformer secondary voltage and currents. The FFT analysis is carried out and the output current FFT spectrum is shown in Figure 17.

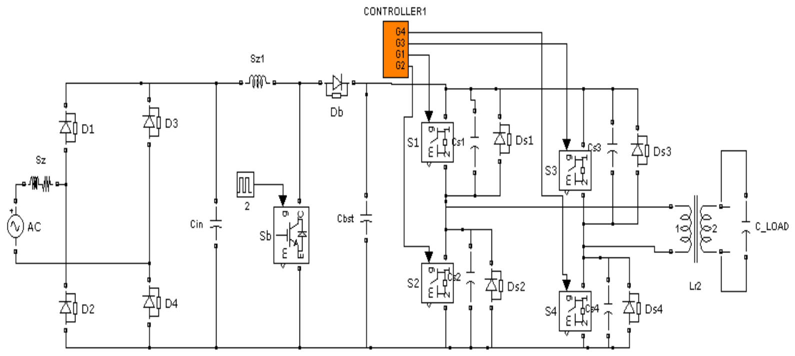

Figure 11. Proposed Power Supply Circuit for Ozonator with PFC

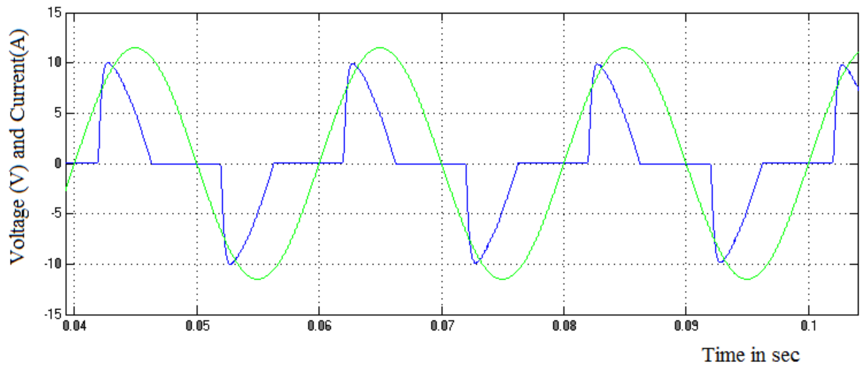

Figure 12. Input Voltage and Current (Scale Volt One Unit=10v)

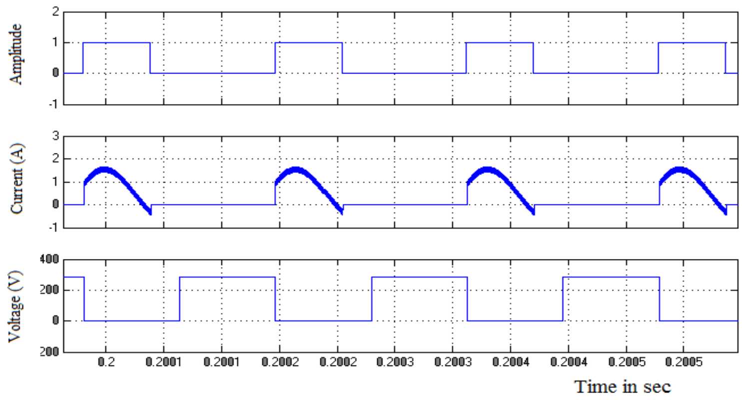

Figure 13. Switching Pulse, Current Through and Voltage across the Switch S2 and S3

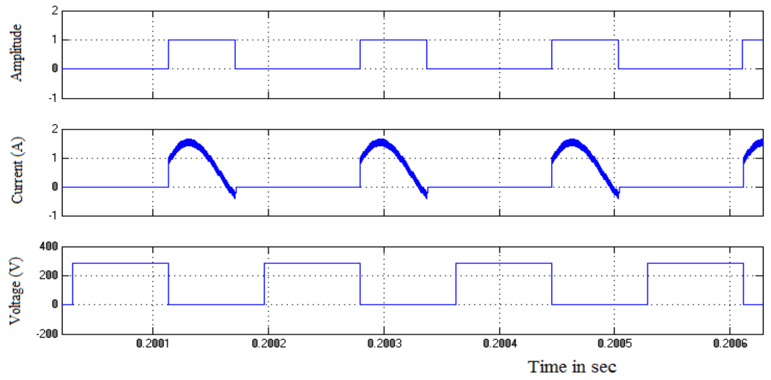

Figure 14. Switching Pulse, Current Through and Voltage across the Switch S1 and S4

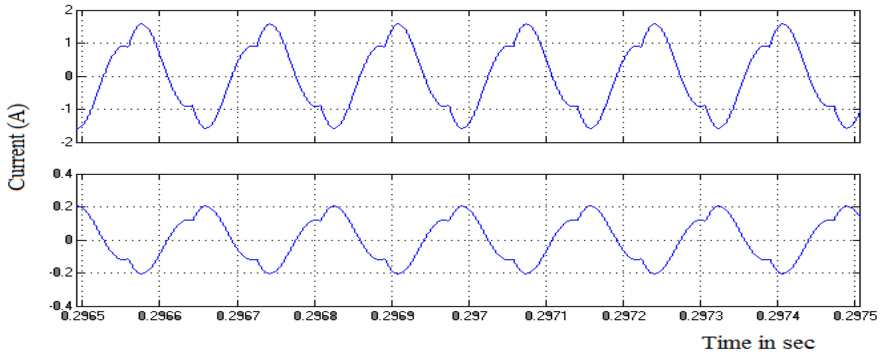

Figure 15. Transformer Primary and Secondary Currents

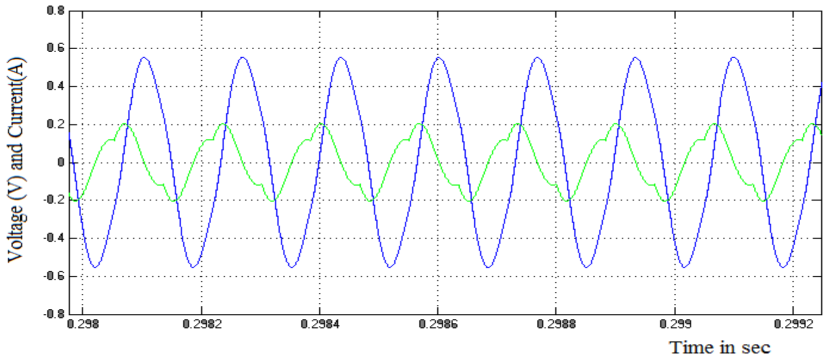

Figure 16. Transformer Secondary Voltage and Current (Scale Volt One Unit=1000v)

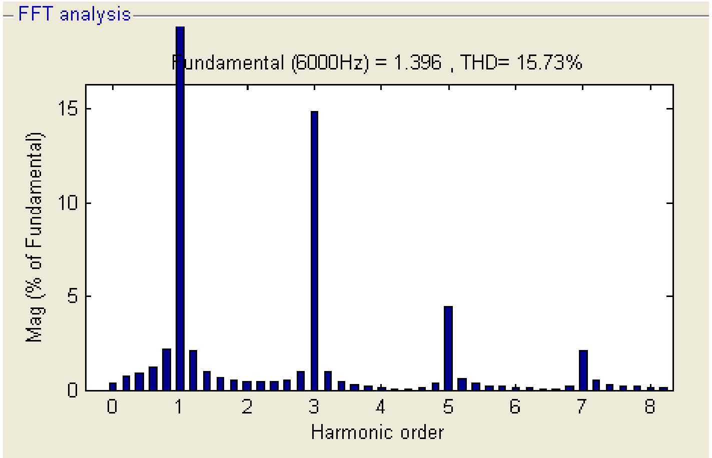

Figure 16. FFT Spectrum of the Output Current

As observed from Figure 12, the supply power factor is improved in the proposed configuration. A comparative study is been carried out between conventional inverter and proposed inverter and it is given in Table 1.

Table 1. Comparative Analysis of Conventional and Proposed Inverter

Parameter	Conventional Inverter	Proposed Inverter
Input DC voltage	300 V	300V
Input PF	0.31	0.81
Output Voltage (Peak value)	5400 V	5470
Input power	427 W	412
Output power	345W	356
Efficiency (%)	80.7	86.4
THD (%)	15.99	15.73

The graph in Figure 17 shows the comparison between input voltage and output voltage. Figure18 shows the comparison between input voltage and efficiency of conventional. The proposed system has higher efficiency which is evident from the graph. The proposed PFC supply system has high efficiency of 88.3% and high power factor of 0.81 compared to the conventional inverter where the efficiency was 80.7% and the power factor was 0.31

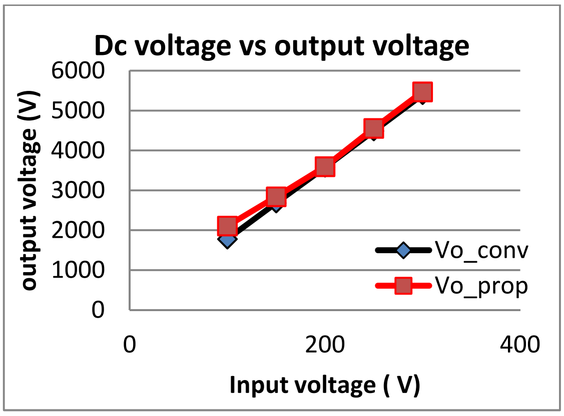

Figure 17. Input Voltage v/s Output Voltage

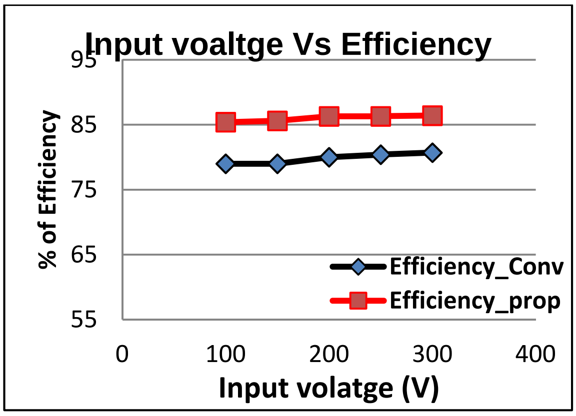

Figure 18. Input Voltage v/s Efficiency Graph

5. CONCLUSION

A boost converter as PFC for inverter feeding a Ozonator was proposed. From the simulation results it is observed that the proposed configuration offer high efficiency of 86.4% compared to the conventional configuration where efficiency was 80.7%. It is also evident from the simulation results that the power factor of proposed supply system is 0.81 which is very much better than the conventional power supply system.

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