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Development of Corona Ozonizer Using High Voltage Controlling of Produce Ozone Gas for Cleaning in Cage

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Abstract: This paper presents development of corona ozonizer using high voltage controlling for cleaning in red-whiskered bulbul cage. This power supply uses full-bridge converter at switching high frequency more than 20 kHz and controls its operation using pulse width modulation (PWM) techniques. Power MOSFET#IRFP450 is controlled by IC#TL494. The highly non-uniform electric field ozone tube of two level insulator cylindrical. The testing of multi-ozone generation system using 3 levels of high voltage controlling are 1 kV, 3 kV and 5 kV and at one-hour, ozone tube yields the ozone generating capacity of 328 mgO_3/hr, 735 mgO_3/hr and 927 mgO_3/hr which ozone gas quantity are 328 mgO_3/hr at 30 minute, 735 mgO_3/hr at 19 minute and 927 mgO_3/hr at 12 minute enable cleaning in red-whiskered bulbul cage.

Key words: corona ozonizer, cage, ozone gas, electric field, converter

1. Introduction

Nowadays, ozone gas is widely brought to use for living such as using ozone to clean the vegetables instead of manganese to kill diseases and reduce a quantity of chlorine in water. Bringing ozone to clean the air purely has some drawbacks. For examples, if it is used too much concentrated, it can irritate to the body. It is useful to the health if quantity is properly used and is applied for work suitably. This paper presents a study of the effect of high voltage adjustment using duty cycle controlling in Power MOSFETs to the ozone quantity. The high voltage high frequency is constructed by using a principle of switching power supply. A high voltage high frequency is supplied to the load, which are two-layer electrode in series, for producing ozone gas. The generating ozone gas is based on the principle of spreading molecules of oxygen. It will produce ozone gas from the equation of $O_2 + O = O_3$ [1-3].

2. Materials and Methods

The main factor of air comprises 79% nitrogen (N_2) and 21% oxygen (O_2) [2]. The rest is inert gas and steam. Ozone gas is the gas, consisted of 3 atom oxygen, under unstable status, easy dispersion that is depended on the environment and density of the productive quantity. The procedure of production consists of the generating free oxygen atom process from oxygen molecule in the air. After that free oxygen atom is together with oxygen molecule to obtain ozone gas (O_3) which is brought to use in industrial cured system. The occurring ozone gas process forms from 2 processes — ionization process and dissociation process. The ionization, spreading of gas, is the increment of electron avalanche leading to breaking down in insulator, which electric current is considered through the border line of insulator. The following occurrence is the heat because the current flows in insulator, which is from the occurred breaking down. This causes the low related energy of ozone gas

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disintegrated. Therefore, the ozone gas production should not make a break down. That is electron energy from electric field, having energy less than ionization energy but this energy is enough to separate the oxygen atoms [1, 3].

2.1 Block Diagram of Corona Ozonizer

Fig. 2 shows the blue corona ozonizer, which is constructed from the ac high voltage high frequency switching power supply. The ac input voltage is 24 Volt, 50 Hz supplied to rectifier circuit in order to produce the dc voltage of 34 Volt. From the dc voltage to ac voltage, the inverter controlled by Pulse Width Modulation (PWM) is used to obtain the high frequency of 20 kHz. The high voltage of inverter from the primary side steps up to high voltage of the secondary side at 1 kV–5 kV in order to produce the High Frequency High Voltage (HF-HV) into the ozone tube. Then, it generates the ozone gas.

2.2 Co-core cylinder: Ozone Tube's Structure

Electric field flux is on the radius line and the surface of cylinder. Potential surface is based on Maxwell's equation $Q = \int_s^{\rightarrow} D \cdot \vec{dA}$ for co-core cylinder of 1 radius length: r ($r_1 \le r \le r_2$).

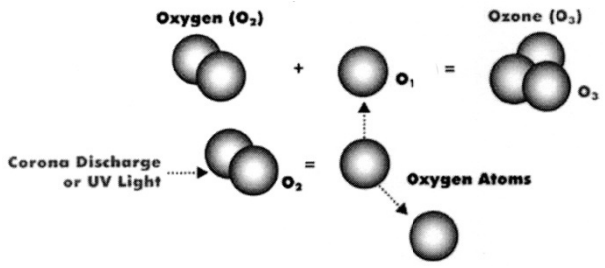


Fig. 1 The process of ozone gas generating.

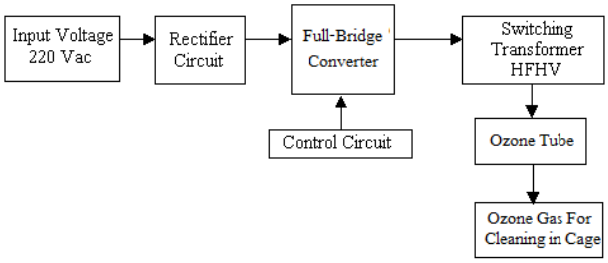


Fig. 2 Block diagram of corona ozonizer.

The electric field is given by [3]

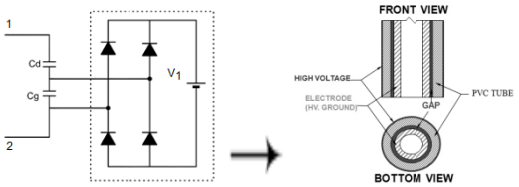
$$Er = \frac{Q}{2\pi\varepsilon l} \cdot \frac{1}{r} \tag{1}$$

Voltage (V) across between both cylinders is given by

$$V = \int_{r_1}^{r_2} E_r dr = \frac{Q}{2\pi\varepsilon l} \ln \frac{r_2}{r_1} \frac{dr}{r}$$

$$V = \frac{Q}{2\pi\varepsilon l} \ln \frac{r_2}{r_1}$$

$$Er = \frac{V}{r \ln \frac{r_2}{r_1}} \; (r_1 < r < r_2) \tag{2}$$



(a) (b)

Fig. 3 (a) Equipvalent circuit of electrode tube and (b) Ozone tube's structure [4].

The maximum electric field stress is occurred on the inside of cylinder's surface given by:

$$E_{MAX} = E_{r_1} = \frac{V}{r_1 \ln \frac{r_2}{r_1}} \tag{3}$$

2.3 Ozone Tube Designing for Generate Ozone Gas

The designing 2 layers co-core cylinder ozone tube is based on the principle of designing ozone gas quantity. The ozone gas well occur in the non-uniform electric field. Thus, the designing of electrode tube of 2-layer insulators is chosen because insulator permittivity is different. It is appropriate with non-uniform electric field that cause the electric field stress in each layer. Therefore, the design of 2-layer co-core cylinder is composed of

- PVC, the first insulator, is chosen because it has so a little effect to generating ozone, where permittivity (ε_1) = 5
- Air is the second insulator with permittivity (ε_2) = 1

- Cathode frilled aluminum (aluminium tube) in fillament coil inside of the PVC's electric insulator is used. The reason is aluminum has a high conductivity.
- Anode is a cylinder stainless steel because stainless steel does not effect to generate ozone gas.

2.4 The Calculation of Ozone Tube

From Fig. 4 shows the calculating of electrode tube at l = 35 cm, r_1 = 2.3 cm, r_2 = 2.5 cm, r_3 = 2.7 cm, ε_1 = 5 of PVC and ε_2 = 1 of air.

The energy interval per volume is between 5.58 kWh/m^3 and 7.73 kWh/m^3 because there is 21% of oxygen so the energy is 1.172 kWh/m^3 -1.620 kWh/m^3.

3. Results and Discussions

3.1 Test of Inverter and Ozone Gas Analysis

The high frequency high voltage AC inverter is controlled by IC#TL494 [4] as shown in Fig. 5. Switching devices, Power MOSFETs#IRFP450, are used in the inverter controlled by the PWM strategy from IC#TL494. The switching frequency is 20 kHz. The energy from inverter can transfer through a switching transformer to produce high frequency high voltage supplying the ozone tube [1, 3].

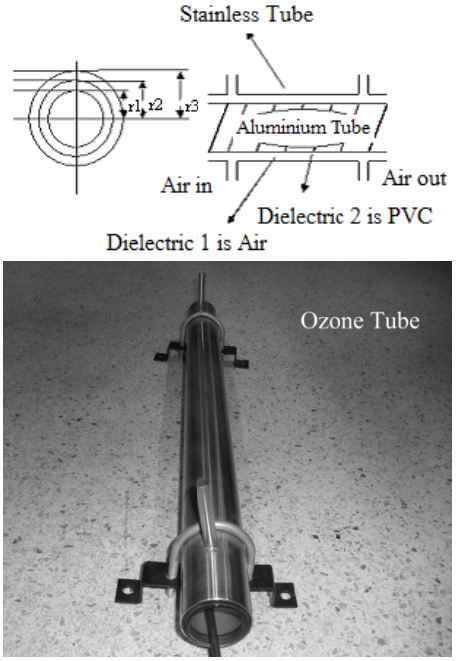


Fig. 4 The structure of ozone tube.

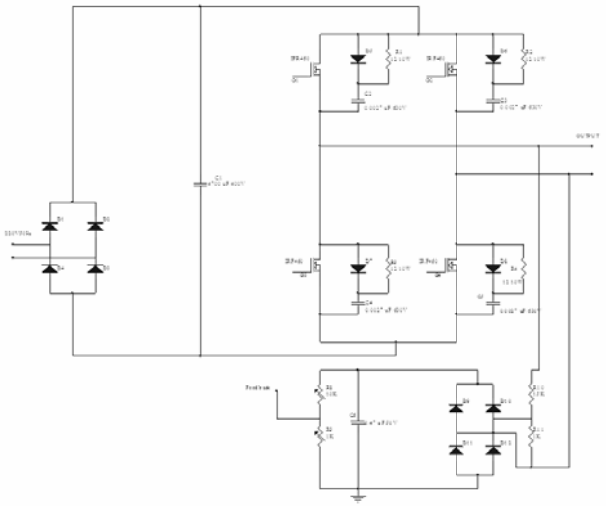


Fig. 5 Full-Bridge inverter circuit for ozone tube.

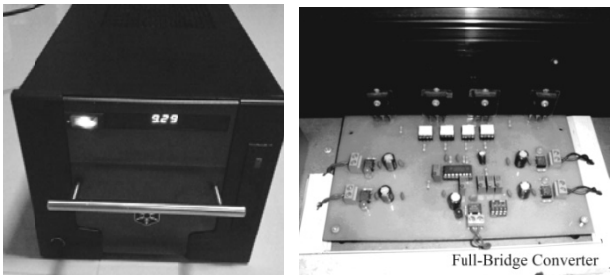


Fig. 6 Inverter circuit for ozone tube.

3.2 Testing of Breakdown Voltage of Ozone Tube

The average value of breakdown voltage is

$$V_{Breakdown(avg)} = \frac{55}{10} = 5.5\ kV_{(avg)}$$

Use 5 kV because breakdown voltage protection.

3.3 The Relationship between the Output High Voltage (V_{OUT} (kV)), Ozone Quantity (mgO_3/hr) and Cleaning in Cage

Table 1 The relationship between the output high voltage (V_{OUT} (kV)), ozone quantity (mgO_3/hr) and cleaning in cage.

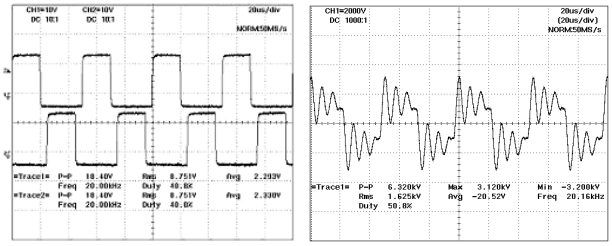
V_{OUT} (kV)	Ozone quantity (mgO_3/hr)	Cleaning in cage
1	328	✓
3	735	✓
5	927	✓

Where parameters of Table 1 are

- V_{out} (kV) is the output voltage of high voltage supply

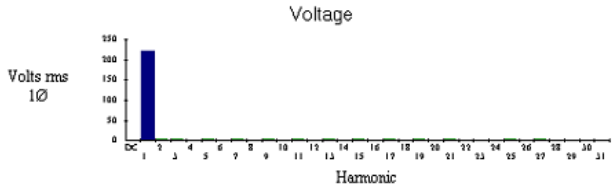
- Ozone gas quantity (mgO_3/hr) is ozone gas is generated by corona ozonizer

3.4 The Results of Measurement of V_{GS} of Power MOSFETs and Output Voltage of High Frequency High Voltage (HF-HV) Transformer as Shown in Fig. 7

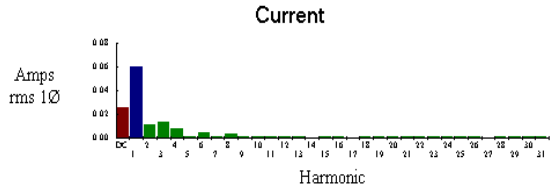


(a) (b)

Fig. 7 (a) Drive signal of Power MOSFETs and (b) Secondary (output) voltage of HF-HV transformer at 3 kV.



(a)



(b)

Fig. 8 (a) Harmonics orders of input voltage of ozone generator at 223 V and (b) Harmonics of input current of ozone generator at 0.06 A.

4. Conclusions

The experiment of corona ozonizer can be divided into 2 steps of experiments. The first experiment results are from circuit parts generating switching frequency that can be more than 20 kHz and the duty cycle of PWM control at 0.35 to drive Power MOSFETs in the full-bridge inverter and transfer energy to transformer and the last experiment are quantity of generate ozone at high voltage controlling are 1, 3 and 5 kilo-Volt (kV). The results are the relationship between high voltage and the quantity of generated ozone gas. That is the more high voltage increases, (also more ionization in

Fig. 9 Red-whiskered bulbul cage.

ozone tube), the more quantity of ozone gas are generated, while enable cleaning in red-whiskered bulbul cage. Ozone gas quantity measurement using Photometric O_3 Analyzer–Model 400E of ALS Laboratory Group (Thailand) CO., LTD. The designed blue corona ozonizer also produces current harmonics which provide the effect to the power system. Therefore, the harmonics filter should be designed to decrease the harmonics quantity of current.

In the future, the quantity of generated ozone can solve other ways such as the environmental problems. In addition, it can use a lot of other usefulness.

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