

Advance Method for Calculating Ozone Chamber Parameters

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ABSTRACT: Dielectric Barrier Discharge is considered to be an efficient method to produce ozone as compared to other method. But for the parameter calculation it becomes necessary to employ RF amplifier which ultimately increases the cost. Parameters can be calculated only at resonance condition which occurs when the frequency of RF amplifier is matched with ozone chamber and transformer. Therefore to obtain resonance condition RF amplifier is necessary. The present technique proposes a circuit which is used to calculate the chamber parameters without gate drive circuit, RF amplifier and lissajous plot. It also eliminates the problem of core saturation due to utilization of high frequency inductor which acts as alternative of transformer in the circuit to produce required voltage levels to drive the ozone cell. Hence a new approach without a transformer.

Keywords- DBD, Full bridge inverter, PSPWM, Transformer less ozone generator, Variable inductor

I. INTRODUCTION

Ozone is the tri-atomic state of oxygen, i.e. it is a molecule comprising of three oxygen atoms. The ozone is an active modification of the oxygen. It has clear blue color and spicy odor, it is more soluble in water and much more active than the oxygen, it is considered the more powerful oxidant over the earth and it has a lot of applications. Due to its chemical properties, it is used as a disinfectant and germicidal. It is employed in air and residual water treatment, deodorization, oxidation process, dental medicine, recycling of plants, cooling towers, food sanitation etc. An important property of the ozone is the absence of toxic substances as a result of its application to disinfect water or other substances, by this reason is commonly used by purification and deodorization industry. For industrial purposes ozone is exclusively generated in large installations using dielectric-barrier discharges. Ozone is a potent germicide and one of the strongest known oxidants. In many applications it can replace chlorine thus causing less environmental concern. Although ozone itself is toxic, ozone treatment leaves no toxic residues that have to be treated or disposed of.

The traditional application of ozone is for water treatment which has a long tradition especially in Europe. About one hundred years ago it was realised that the germicidal and viricidal effects of ozone can provide safe drinking water in areas previously endangered by cholera and typhus epidemics. The first major ozone installations went into operation in Nice in 1907 and in St. Petersburg in 1910. Although up to recently many countries have preferred chlorine chemistry for water treatment because of its lower cost there is a strong tendency now to switch to ozone. The main targets for using ozone in water treatment are disinfection, control of disinfection by-products (tri halo methane), colour, taste, odors, pesticides or the removal of iron and/or manganese. The second important growing large-scale use of ozone is in the paper industry. By combining oxygen, ozone and hydrogen-peroxide bleaches, pulp can be treated in a closed circuit without using chlorine.

II. METHOD TO PRODUCE OZONE

As a commercially demanded treatment, there have been years of research and development put into methods of ozone production. Today there are four recognised methods:

1. Corona Discharge
2. Ultraviolet Radiation
3. Electrolysis
4. Radiochemical
5. Dielectric Barrier Discharge.

Any method of generating ozone relies on applied energy to break the bonds holding the oxygen atoms in a molecular form, allowing them to dissociate and then re-form as ozone. The applied energy is random in its

action, resulting in a high level of friction in there action process. For this reason ozone production is inefficient, and is accompanied by a large percentage of waste heat.

2.1. Corona Discharge

Corona discharge is the condition created when a high voltage passes through an air gap. In the case of ozone production, this high voltage transfers energy for the breaking of the O₂ molecule, allowing the formation of 3-atom oxygen molecule ozone. This method is today the most widely used for commercial ozone production.

2.2 Ultraviolet Radiation

As indicated, the formation of ozone from oxygen is endothermic, i.e. it requires energy. When exposed to light an oxygen molecule in a ground state will absorb the light energy and dissociate to a degree dependent on the energy and the particular wavelength of the absorbed light. The oxygen atoms then react with other oxygen molecules to form ozone. Each wavelength of light favours different reactions and their quantum yield. The breakdown of the oxygen molecule has a higher yield at wavelengths less than 200nm. However just as oxygen absorbs light, so does ozone. The dissociation or photolysis of ozone has its greatest yield between 200 and 308nm. For effective ozone production it is therefore necessary to utilize a short wavelength ~185nm. In theory, the yield of O₃ from 185nm UV light is 130g/kWh of light. As lamp efficiencies are so low, ~1%, the production per kWh from the power source is greatly reduced. In practice, with the present state of development, UV lamps can only produce about 20gO₃/kWh of ozone when using oxygen as the feed gas. However, they are more commonly used with vacuum injection systems drawing atmospheric air over a UV lamp tube, and generate 1-2gO₃/kWh in concentrations of 0.1% w/w of air. These are very simple in design, require no air preparation and are ideal for small applications such as small fishponds, laboratory work, and dour elimination.

2.3. Electrolysis

Electrolysis is the process in which an electric current is passed through a liquid, causing a chemical reaction, resulting in the evolution of gases. In relation to ozone production, water can be used as the electrolyte leading to direct diffusion, or special electrolytes such as H₂SO₄ can be used and ozone gas drawn off and diffused and contacted by the usual methods.

Work has been done with different electrolytes and anode materials to improve the efficiency of production and minimize the corrosive reactions on the anode surface. The concentration of ozone produced is determined by the current density acting on the cell. With the use of an ozone gas evolving cell as depicted in this diagram, high concentrations of ozone, at least 10% can be achieved. The use of electrolysis for ozone production is presently limited to small units used for applications that require high concentrations of ozone, and in-situ diffusion of ozone into ultra pure water. Currently, whilst their capital cost is favourable compared to corona discharge units, the operating costs are significantly higher. Further development needs to be done on the composition of electrolytes and cathode/ anode manufacture before they become a commercially viable production method.

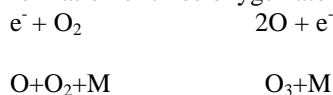
2.4. Radiochemical

High energy irradiation of oxygen by radioactive rays can promote the formation of ozone. While high yields have been achieved under specific conditions using oxygen, the best results from an air flow through system at atmospheric pressure, has been ~ 3-4 mg/m. The process is fraught with complications in filtering harmful isotopes and it is not viewed with potential use in commercial applications.

2.5. Dielectric Barrier Discharge

Dielectric-barrier discharges (DBDs), also referred to as barrier discharges or silent discharges have for a long time been exclusively related to ozone generation and is one of the most efficient method to produce ozone. The most important characteristic of dielectric-barrier discharges is that non-equilibrium plasma conditions can be provided in a much simpler way than with other alternatives like low pressure discharges, fast pulsed high pressure discharges or electron beam injection. Its flexibility with respect to geometrical configuration, operating medium and operating parameters is unprecedented. Conditions optimised in laboratory experiments can easily be scaled up to large industrials installations. Efficient low cost power supplies are available up to very large powers. Most technical ozone generators make use of cylindrical discharge tubes of about 20-50 mm diameter and 1-2 m length. Glass tubes are mounted inside stainless steel tubes to form a narrow annular discharge space. The high voltage electrode is formed by a conductive coating, e.g. a thin

aluminium film on the inside of the glass tubes. The preferred dielectric material is borosilicate glass (Pyrex, Duran). In advanced ozone generators also layered enamel coatings with optimised dielectric characteristics are used on steel tubes. Large ozone generators use several hundred tubes and produce up to 100 kg ozone per hour. Since the efficiency of ozone formation decreases strongly with rising temperature, modern ozone generators use narrow discharge gaps to ensure efficient heat removal. Typical gap spacing are in the range of 0.5 to 2 mm Dielectric barrier discharge (DBD) is the electrical discharge between two electrodes separated by an insulating dielectric barrier. The process uses high voltage alternating current. The gap distance between the electrodes is about 1 mm in ozone generators. A multitude of random arcs form between the two electrodes during operation, as the charges collect on the surface of the dielectric, they discharge in microseconds, leading to their reformation elsewhere on the surface. Oxygen gas is flowing through the electrodes and due to the discharging arcs, the oxygen is split into two single oxygen atoms. The oxygen atoms will eventually recombine to the formation of three oxygen atoms: ozone (O₃).The major reaction taking place are as follows:



Where M is the third body such as reactor wall or gases molecules if air is injected.

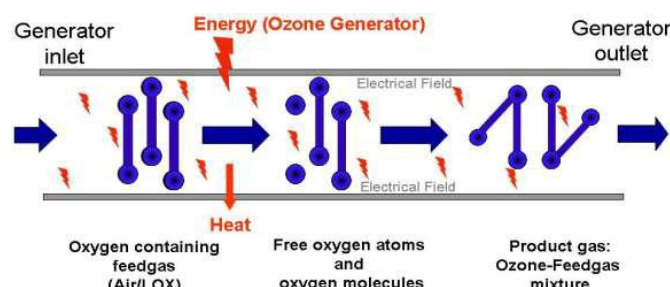
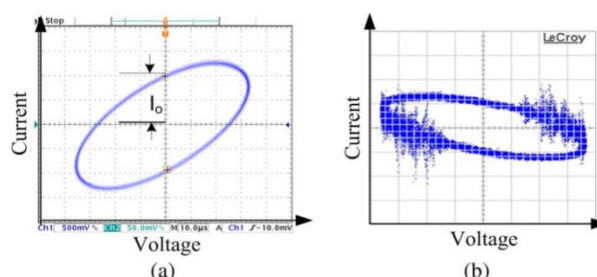
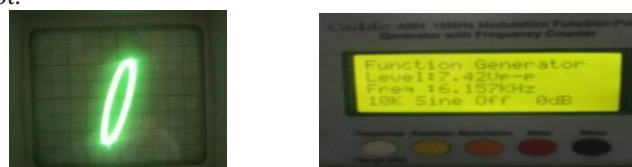


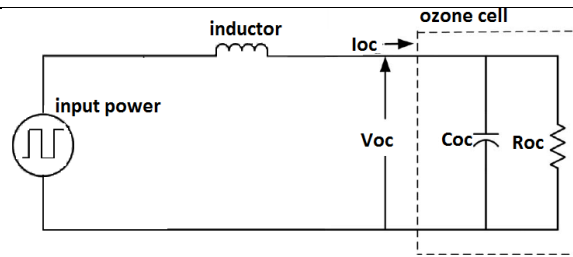
Fig 1: generation of Ozone using DBD

Modern high-power ozone generators use thyristor controlled frequency converters generating square wave currents at frequencies between 0.5 and 5 kHz. This way power levels up to 1 MW/unit can be handled [8],[9].

III. PROPOSED TOPOLOGY

Mainly when transformer is used in large application it suffers with problem of core saturation and due to this it puts barrier on construction of small transformer. Another disadvantage is that when DBD is used to produce ozone the chamber parameter is calculated by employing RF amplifiers. At frequencies below 10 kHz, the Lissajous shape resembles a parallelogram. As soon as frequency increases beyond 20 kHz the lissajous figure becomes circular and it gets splattered [1]. The proposed topology is to use the high frequency variable inductor to produce a high voltage in order of 1.8 to 3.3Kv and to calculate the chamber parameters without RF amplifier and lissajous plot.





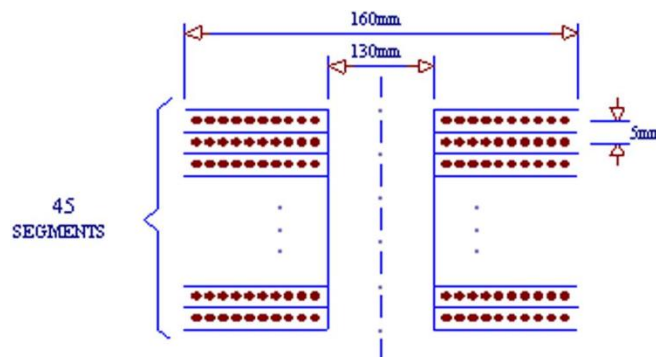
$C_{oc} = C_a + C_g$
 Where as

C_a - capacitances due to discharge gap
 C_g - capacitances due to dielectric sheet

A. POWER SUPPLIES:

Power circuit consists a ac source of 230v which is fed to the rectifier circuit. Capacitor is connected across rectifier which acts as a filter to obtain pure dc. This output of rectifier is fed to phase shift PWM inverter. The necessity of this inverter is that it controls the output voltage as well as output quantity by varying phase shift of the switching pattern[10].

B. INDUCTOR:



Implementations with and without magnetic cores were considered. Although implementation with magnetic cores provides a better efficiency, the inductor is implemented without magnetic cores [4] because of cost concerns due to the large number of cores. The value of inductor is selected in such a way that it produces the required voltage levels which is obtained from the transformer through other methods[6].

C. Ozone Cell

Ozone is produced in the corona as a direct result of power dissipation in the corona. Electrons are accelerated across an air gap so as to give them sufficient energy to split the oxygen double bond, thereby producing atomic oxygen. These oxygen atoms then react with other diatomic oxygen molecules to form ozone[6],[7].



D. Phase shift PWM Inverter

Phase shift PWM inverter is used to maintain the zero voltage switching (ZVS) condition and it is used to control the output parameters. The working principle is same as that of PWM inverter. It consist of four MOSFET's which is used to control the output parameter [2], [3].

III. SIMULATION AND RESULT

Proposed work is simulated in Matlab/Simulink. The value of inductance is selected between 95mh to 330mh. Resonant frequency occurs which is used to calculate the chamber parameters. Tabulation made for $L_s=95\text{mH}$, $C_{oc}=161.5\text{pf}$, $R_{oc}=966\text{K}\Omega$ is as follows

Phase Angle Shifted In \square	Chamber Voltage In Kv	Chamber Current In A	Power consume IN W
0	3.8	0.16	21.66
60	2.0	0.02	6.0
120	1.9	0.08	5.41

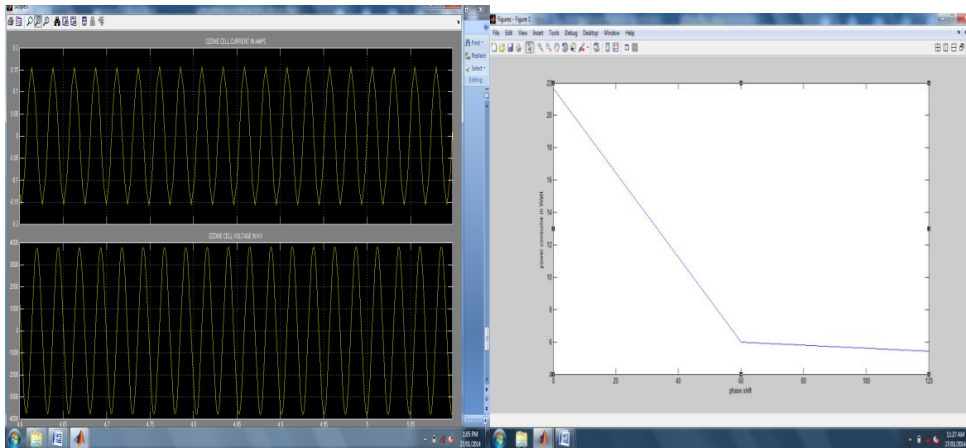


Fig 3: simulation result showing chamber voltage and current
Fig 4: phase shift Vs power consume by chamb

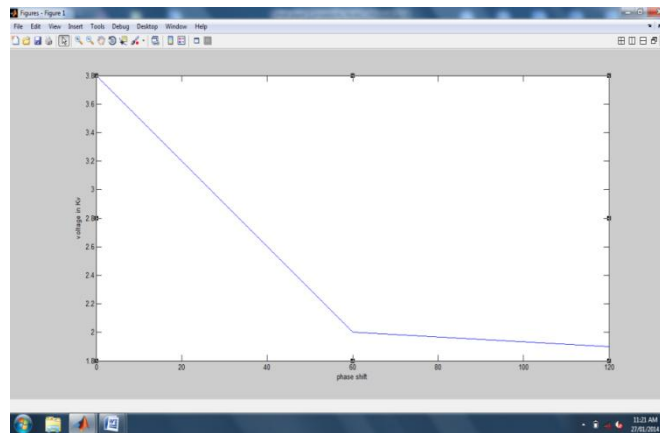


Fig 5: phase shift Vs output voltage

VI. CONCLUSION

In this paper transformer less resonant inverter is simulated, the result being satisfactory, and it is tabulated too. In this circuit without RF amplifier is modeled in Matlab And the value of inductance, capacitance and power is tabulated. The results Obtained through this method is being satisfactory and is similar to the existing Method .Graph is plotted between phase shift and chamber voltage and between phase shift and power. From this topology it is proved that the chamber parameters can be calculated by eliminating the gate drive circuit and RF amplifier. Also it is find that the output voltage can be control by varying value of inductance and also by changing phase shift of inverter by using PSPWM.

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