The effect of the magnetic field on an ozone generator fed by a non-sinusoidal half-bridge resonance inverter

by Fri Murdia

Submission date: 21-Nov-2019 09:17AM (UTC+0700)
Submission ID: 1218331541
File name: Journal_IJEEIITB.docx (5.54M)
Word count: 5256
Character count: 26799

The effect of the magnetic field on an ozone generator fed by a non-sinusoidal half-bridge resonance inverter

Fri Murdiya
Dept. Electrical Engineering, Universitas Riau, Pekanbaru, Indonesia
Jl. HR Subrantas KM 12,5 Panam, Pekanbaru,Indonesia
Budhi Anto
Dept. Electrical Engineering, Universitas Riau, Pekanbaru, Indonesia
Jl. HR Subrantas KM 12,5 Panam, Pekanbaru,Indonesia
Febrizal
Dept. Electrical Engineering, Universitas Riau, Pekanbaru, Indonesia
Jl. HR Subrantas KM 12,5 Panam, Pekanbaru,Indonesia
Amun Amri
Dept. Chemical Engineering, Universitas Riau, Pekanbaru, Indonesia
Jl. HR Subrantas KM 12,5 Panam, Pekanbaru,Indonesia

Abstract

Magnetic field-induced dielectric barrier discharge (DBD) as an ozone generator is a unique equipment. The position of permanent magnet induces DBD also affects ozone production. There are several methods of permanent magnet placement in inducing DBD. Model 1 is by placing the ring permanent magnet under the cathode electrode tied with Teflon, model 2 is by placing 2 (two) permanent magnet rings above the anode electrode and below the cathode electrode, respectively which is limited by a Teflon solid material and the magnetic conditions are repelling each other, model 3 is by using 2 (two) pieces of ring permanent magnet that placed above the anode electrode and below the cathode electrode which is bounded by Teflon materials and these magnetic conditions are attracting each other. All of these models use permanent magnet beans made of ferrite, which are attached to the surface of the anode electrode. Another unique thing is the use of non-sinusoidal inverters with a maximum voltage of 15 kV in initiating plasma in the air gap that develops from the surface of permanent magnet beans. The plasma produced in model 3 is denser than plasma in models 1 and 2. Then, plasma in model 2 is also denser than that of model 1. It can be seen that a permanent magnet is placed between two electrodes with attraction condition, it can make plasma more tight than model 1 and 2. Furthermore, by adding permanent magnet beans as electrodes, it will increase energy to produce plasma in the gap between the anode electrode and dielectric ceramic. It is shown that the permanent magnet beans enhance the development of plasma in the gap. When the flyback transformer terminal is connected to the anode and cathode electrodes for model 1, the maximum measured voltage is 13.8 kV and the maximum current pulse measured is 690 mA. The results of current and voltage measurements for model 2 show that the maximum voltage is 12.5 kV and the maximum current pulse is 973 mA. For model 3, the maximum current pulse measured is 800 mA and the maximum voltage measured is 11 kV. For all models produce current pulses which indicate micro discharge occurs in the gap between the anode electrode and ceramic dielectric. Of all the models, it appears that the most current pulses are in model 3, which also indicates that this model 3 produces more micro discharge than models 1 and 2. This is also characterized by current pulses of model 2 which are more than models 1. This current pulse occurs when the maximum voltage for all models. It can also be concluded that the maximum voltage and maximum current at discharge for all models are different. When there is a discharge of current suddenly reaches its maximum value for all models. This discharge causes an increase of current in the test circuit. The area of the lissajous model 3 is slightly smaller than the models 1 and 2. The area of lissajous in model 2 is the largest area compared to models 1 and 3. It is seen that the effect of the position of the permanent magnet parallel to the anode and cathode electrodes on the area of the lissajou (discahrge energy) is not very significant. It can be concluded that model 3 occurs current pulses more than models 2 and 1 which is indicated that there is a more ionic discharge that can increase the ionization process on oxygen which further it will produce more ozone gas than model 1 and 2. Here, it can be seen that the ozone concentration produced from model 3 is higher than that of models 2 and 1. Model 2 also produces higher ozone concentrations than model 1The effect of induction of ring permanent magnet with attractive conditions is the new thing to improve the performance of ozone generators.

Keyword : DBD, magnetic field, non-sinusoidal inverter, plasma, lissajous, ozone

1. Introduction

Dielectric barrier discharge (DBD) was first introduced by Siemens which was used as an ozone generator. Simens began his experiment to examine the effect of dielectrics on the plasma produced and this plasma was used to react oxygen compounds to ozone gas [1]. The main components of this dielectric barrier discharge (DBD) are high voltages in kilovolts with system frequencies from Hz to kilo Hz, anode and cathode electrodes and dielectrics made of ceramics, glass, mica and etc. The construction of the barrier discharge dielectric (DBD) is given in figure 1 below [2]. The dielectric barrier discharge (DBD) application has fulfilled various aspects of science such as ozone generators used for drinking water treatment, waste treatment, waste gas treatment, plasma medicine, surface treatment and etc [2-7].

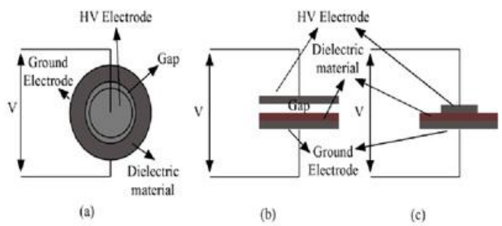


Figure 1. Dielectric barrier discharge arrangement. (a). Cylindrical DBD , (b) Planar DBD, (c) Surface DBD.

The ozone formation reaction process which is more dominant when the high pressure on the gas is given in the following reaction as equation (1) [8].

$$O + O_2 + M \rightarrow O_3 + M \quad (1)$$

This chemical reaction does not always succeed in forming an ozone gas, but this reaction sometimes produces oxygen gas and molecular M as in the reaction equation (2) below.

$$O + O + M \rightarrow O_2 + M \quad (2)$$

at the case of discharge of electric charge in the air, molecule M is molecular oxygen or nitrogen. Ozone under certain conditions can react again with nitrogen given in equations (3) and (4).

$$NO_2 + O_3 \rightarrow NO_3 + O_2 \quad (3)$$
$$O + NO_3 \rightarrow O_2 + NO_2 \quad (4)$$

There are two-steps process of ozone generation in a non-equilibrium discharge in air at atmospheric pressure. First, oxygen atoms dissociate to an oxygen molecule with the threshold energies [9,10] for these processes are:

Table 1. Threshold energy in the oxygen ionization

Process	Threshold energy [eV]
$O_2 + e \rightarrow O^- + O$	4.2
$O_2 + e \rightarrow O + O + e$	5.58
$O_2 + e \rightarrow O + O(^1D) + e$	8.4

Second, oxygen ion reacts with molecule O_2 and create an ozone molecule that requires the presence of electrons with these energies.

Nowdays, many researchers conduct a dielectric barrier discharge (DBD) to be used as an ozone generator. Kamel examined surface dielectric barrier discharge (SDBD) and volume dielectric barrier discharge (VDBD) as an ozone generator with cylindrical geometry. This DBD has cooling media. This study shows that cooling media can improve the performance of ozone generators [11]. Some researchers also examined ozone generators using power supply impulses in order of nanosecond and managed to regulate spark discharge to produce the ozone well [12-15]. The mini impulse generator prototype was also successfully made by Waluyo which was used for high voltage purposes [16]. Murdiya uses a half bridge resonance inverter power supply and is successfully combined with a dielectric barrier discharge (DBD) to produce high voltage plasma [17].

The effect of the magnetic field on the high voltage plasma between the electrode and the dielectric has been investigated by Park. Park uses needle electrodes as high-voltage electrodes placed inside the gap between the electrode and dielectric [18]. Murdiya also examined the influence of magnetic fields on plasma produced by surface barrier discharge (SDBD) and showed things that were different from DBD without magnetic fields. It is shown that plasma with the influence of magnetic fields is denser than plasma without a magnetic field [19]. Pakarek also examined the effect of permanent magnets on the development of high voltage plasma in the gap between a needle and a dielectric. Position of needle electrode parallel to permanent magnet. The results of the study show the effects of magnetic fields affect the movement of gas molecular ions [20]. Liu also began the study by comparing plasma generation with magnetic field induction and not induced by magnetic fields and he also did the arrangement of plate electrodes and dielectrics in magnetic field. Liu also focused on the nanosecond power supply connected to a high-voltage electrode. This experiment results in the fact is the plasma moving above the dielectric surface that induced by magnetic fields and it is slightly different with the plasma without induced by magnetic fields [21].

Murdiya used a permanent magnet with an intensity of 315 mT in a dielectric barrier discharge (DBD) experiment as an ozone generator. Magnetic fields with magnetic induction of around 300 mT are also used in dielectric barrier discharge (DBD) for the wettability of polypropylene. Pakarek uses permanent magnets with 60 mT induction in dielectric barrier discharge (DBD) for ozone production [17, 22,23].

Dielectric barrier discharge (DBD) induced by permanent magnetic fields for ozone production has been carried out in this research. The effect of adding a permanent magnet that induced a dielectric barrier discharge by placing two permanent magnet rings above and below the anode and cathode electrodes. Otherwise, ferrite permanent magnet beans were also used as additional electrodes and they were attached to the anode electrode surface. There were three models of permanent magnet ring positions: 1. The permanent magnet ring was placed under the cathode electrode, model 2 was by placing the permanent magnet ring above and below the anode and cathode electrodes under the repulsion condition between the permanent magnet rings and model 3 was the same as the second model with the difference in the condition of permanent magnets attracting each other. The power supply used was a non-sinusoidal inverter with a maximum voltage of 15kV. In this study, the characteristics of plasma, current and voltage characteristics, Lissajous diagrams and ozone concentrations produced from several models were examined.

2. Experimental procedures

2.1 High voltage generator circuit and experiment set up

The complete electronic circuit of a nonsinusoidal half bridge resonance inverter is given in figure 2 below. This inverter input is supplied from a direct current (dc) power supply with a voltage of 18 volts dc. For the MOSFET control circuit side on this inverter is equipped with IC CD4047 which is a PWM IC (pulse width modulation). In this electronic circuit, six MOSFETs that are connected in parallel and form a half bridge circuit in order to enlarge the current into the LC resonance circuit. In order to produce oscillation currents, this circuit is equipped with an inductor of 1mH and is connected in series with capacitors with varying values of 470nF, 150nF, and 1uF, respectively. In this test, the selected capacitor is 150 nF. The output of the resonance circuit is connected to the low voltage side of the flyback transformer with the primary coil is a center tap with some turns 10/2. The high voltage side of the flyback transformer is connected to the anode and cathode electrodes as given in figure 3. The photograph of the complete ozone generator is depicted in figure 4. Nonsinusoidal high voltage generator fed by the half-bridge resonance inverter circuit applying a voltage of 18 Vdc is connected to the primary side of the flyback transformer. The high voltage side of the flyback transformer is connected to the high voltage DBD terminal. The measurement of the output voltage of the flyback transformers using a voltage divider with a ratio of 1,000: 1 made in Taiwan with the brand of SEW) was connected to the anode electrode terminal, and the output was also connected to a digital oscilloscope (Hantek 6204 BC). The discharge current in the DBD circuit was measured by using a current probe (Hantek CC65), and it was also connected to a digital oscilloscope. In this research, we practice how to produce ozone gas by injecting free air into the DBD with the help of a small fan. Ozone concentration data was recorded by an ozone analyzer HT-E-O3 made in Hong Kong.

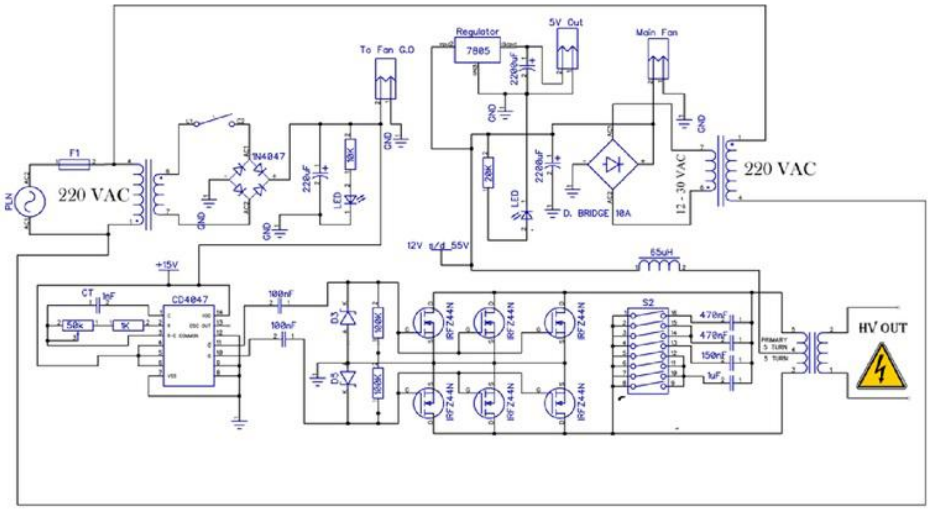


Figure 2. Complete electronic circuit of a nonsinusoidal half bridge resonance inverter

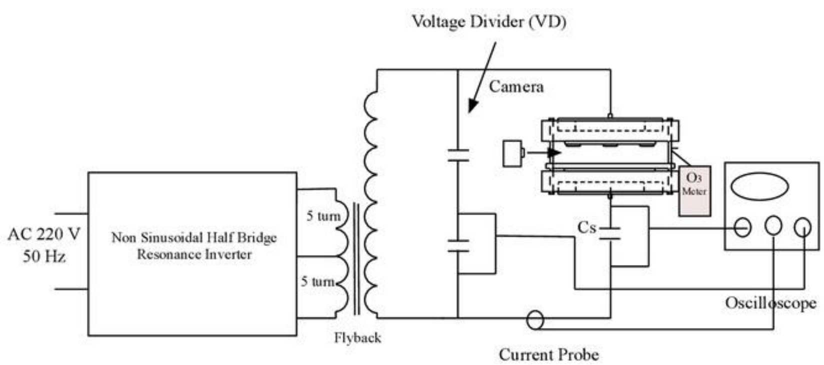


Figure 3. Experiment set up and collecting data

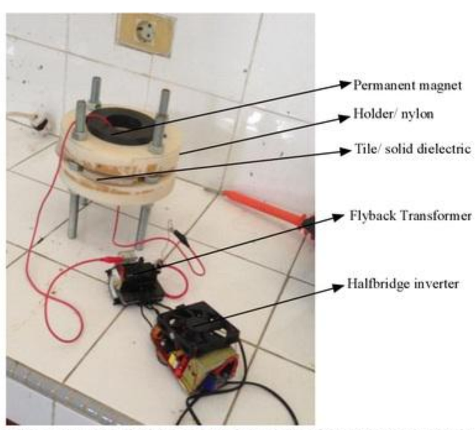
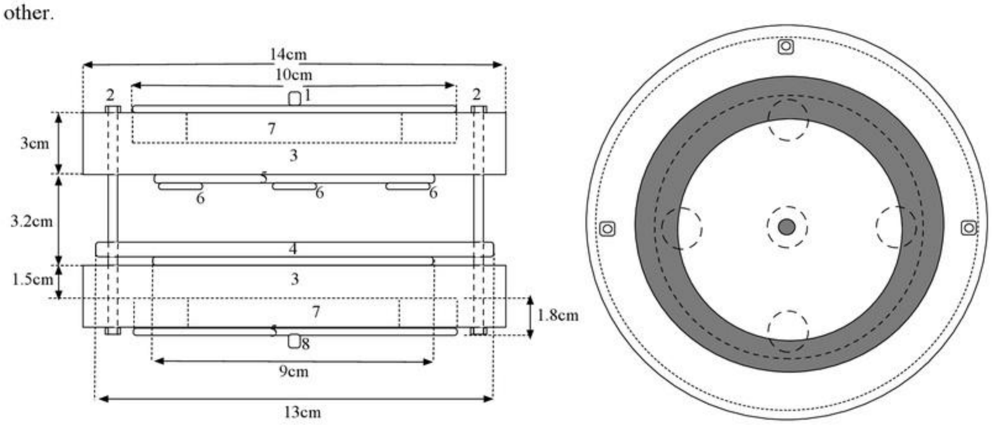


Figure 4. Complete arrangement of ozone generator

2.2 DBD Configurations

The dimensions of DBD can be seen in figure 5 below. We designed a Teflon as a holder of the permanent magnet ring with an outer diameter of 14 cm and the Teflon thickness of 3 cm, respectively. The distance between the holders (Teflon to Teflon) is 3.2 cm. While the outer diameter of the permanent magnet ring is 10 cm. The anode and cathode electrodes used are made of stainless steel with a diameter of 9 cm. The dielectric used in this DBD is the floor tiles (Trademark Platinum), it is made in Indonesia. This ceramic has a diameter of 13 cm with a thickness of 0.7 cm. An anode electrode was attached to 5 (five) small permanent magnets which were useful for initiating a plasma in the gap between the anode electrode and ceramic dielectric as shown in figure 6. This ozone generator was also installed the permanent magnet rings (10cm Outer Diameter) with several models including model 1 was by placing the ring permanent magnet under the cathode electrode tied with Teflon, model 2 was by placing 2 (two) permanent magnet rings above the anode electrode and below the cathode electrode, respectively which was limited by a Teflon solid material and the magnetic conditions were repelling each other, model 3 was by using 2 (two) pieces of ring permanent magnet that placed above the anode electrode and below the cathode electrode which was bounded by Teflon materials and these magnetic conditions were attracting each other.



a. Side view b. Top view

1. HV Termination
2. Bolt and Nut 10M
3. Teflon/Holder
4. Solid dielectric/Tile (Trademark Platinum)
5. Electrode
6. Permanent Magnet Bean (Ferrite Magnet)
7. Circular Permanent Magnet (10 cm OD)
8. HV Termination

Figure 5. View of Dielectric Barrier Discharge (DBD) Chamber

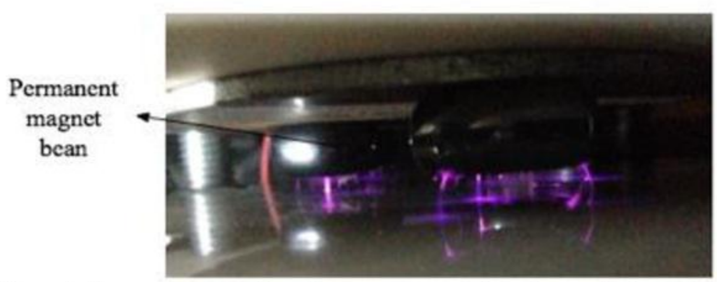


Figure 6. The arrangement of small permanent magnets on the anode electrode.

3. Results and discussion

a. Plasma Photographs

From this experiment, model 1 was designed by placing a permanent magnet ring under the cathode electrode, and plasma was initiated by adding some permanent magnet beans under the anode electrode, while model 2 and 3 were designed by equipping two permanent magnet rings above anode electrode and under cathode electrode. These models also initiated a plasma in the gap by equipped some permanent magnet beans under the surface of the anode electrode. The condition of model 2 was making repulsion between permanent magnet rings while model 3 was attraction condition between permanent magnet rings. The plasma pictures that occur in the gap between the anode and ceramic dielectric electrodes are given in figure 7 below. The light intensity on model 1 is higher than models 2 and 3 as seen in the left photo of figures 7a, 7b, and 7c. This is also supported by the right photo of the images in figures 7a, 7b and 7c which are the results of the invert color. In this condition, it can be seen in figure 7a which has a more extensive black color which is a higher light intensity when compared to figures 7b and 7c. There is some black area in all pictures, and it is indicated that the plasmas produce high-intensity energy. The black area in model 1 is more and more significant than model 2 and model 3.

By adding some permanent magnet beans under the surface of the anode electrode, this method succeeded for producing plasma in all the models. These permanent magnet beans were able to initiate plasma with the accumulation of electric fields and magnetic fields (**BxE**). Plasma appeared on the edge of the permanent magnet beans, and they developed on the surface of the ceramic. These plasmas are non-homogenous plasmas that form non-dense beam between them. Plasmas which have a high light intensity marked in black on the invert color condition energized with high discharge energy. The plasma produced in model 3 is denser than plasma in models 1 and 2. Then, plasma in model 2 is also denser than that of model 1. It can be seen that a permanent magnet is placed between two electrodes with attraction condition, it can make plasma more tight than model 1 and 2. Furthermore, by adding permanent magnet beans as electrodes, it will increase energy to produce plasma in the gap between the anode electrode and dielectric ceramic. It is shown that the permanent magnet beans enhance the development of plasma in the gap. This plasma can also cause erosion on the ceramic/dielectric surface. Model 1 is also found that the solid dielectric (ceramics) is more accessible to erode gradually than models 2 and 3. If an area of ceramic dielectric has a point of erosion, plasma tends to be concentrated in the area of the erosion point. This centralized plasma will glow the dark yellow light. The stages of plasma development on the erosion point are given in figure 8. It can be concluded that this erosion point has decreased its isolation resistance and the electric field is centrally located at that point. The plasma will continue to erode the point until finally, the solid dielectric can conduct the electricity. It is this phenomenon that always occurs in the event of an electrical breakdown in insulation materials which can be explained in theory, the plasma that occurred for all models under conditions of the air pressure of 1 atm. Noise produced by model 1 is also noisier than models 2 and 3.

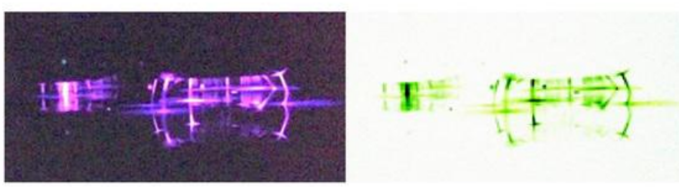


Figure 7a. A permanent magnet under a cathode electrode (Model 1)

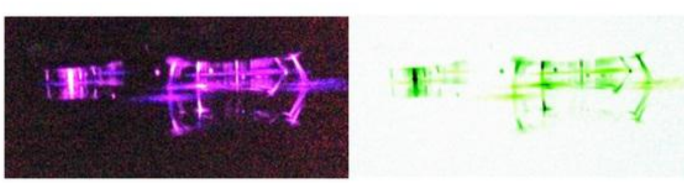


Figure 7b. Two permanent magnets up and bottom electrodes in repulsion condition (Model 2)

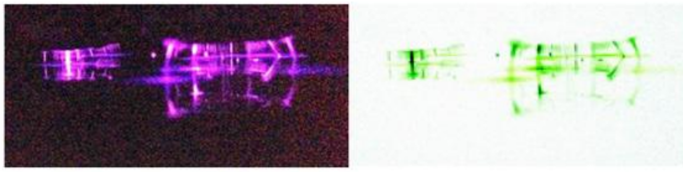
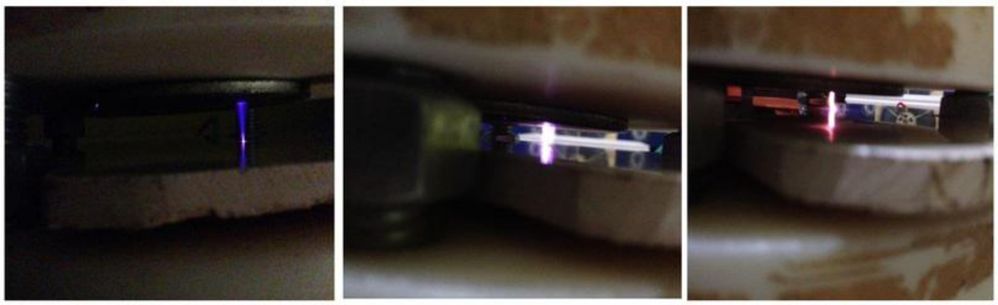


Figure 7c. Two permanent magnets up and bottom electrodes in attraction condition (Model 3)

Figure 7. The results of plasma shooting for various permanent magnet conditions.



First step | Second Step | Third step

Figure 8. Plasma at an erosive dielectric point

b. The voltages and displacement currents

The high voltage side of the flyback transformer in a no-load state produced a nonsinusoidal wave with a maximum voltage of 17.3 kV that was measured by using a voltage probe with a ratio of 1: 1000 and it is given in figure 9a. When the flyback transformer terminal is connected to the anode and cathode electrodes for model 1, the results of current and voltage measurements are given in figure 9b. The maximum measured voltage is 13.8 kV and the maximum current pulse measured is 690 mA. The results of current and voltage measurements for model 2 show that the maximum voltage is 12.5 kV and the maximum current pulse is 973 mA. For model 3, the maximum current pulse measured is 800 mA and the maximum voltage measured is 11 kV. For all models produce current pulses which indicate micro discharge occurs in the gap between the anode electrode and ceramic dielectric. Of all the models, it appears that the most current pulses are in model 3, which also indicates that this model 3 produces more micro discharge than models 1 and 2. This is also characterized by current pulses of model 2 which are more than models 1. This current pulse occurs when the maximum voltage for all models. From figure 9 it can also be concluded that the maximum voltage and maximum current pulse at discharge for all models are different. When there is a discharge of current suddenly reaches its maximum value for all models. This discharge causes an increase of current in the test circuit.

The discharge current in model 1 is depicted in figure 9b. Partial discharge occurs during positive cycles and negative cycles. Partial discharge occurs in a positive cycle that is at zero voltage and up to maximum voltage and then it decreases to zero. Next, it also occurs during a negative cycle of voltage. The current pulse in the positive cycle is more than the negative cycle. The current pulses in model 1 take place intermittently. The pulse amplitude of discharge current in the negative cycle is higher than the positive cycle. The discharge current is shown in figure 9c shows that partial discharge occurs during a positive cycle and a negative cycle as well. During a positive cycle, the partial discharge occurs starting from zero voltage until the voltage reaches the maximum value. The current pulse in the positive cycle appears for 2 us and then reappears in the negative cycle after 6 us of the positive cycle.In a negative cycle, it starts from zero voltage until the voltage approaches the minimum. The current pulse during the positive cycle is more than the current pulse in the negative cycle. This ozone generator model shows that the amplitude of discharge current is greater in the negative cycle than the amplitude of the current in the positive cycle. The ozone generator from model 3 (figure 9d) experiences a discharge of charge every periode of 20 us. The release of this charge occurs for every 15 us. This discharge is initiated when the equipment voltage reaches its maximum value of 11 kV and it will take place even though the voltage value decreases to the minimum value. The electrical discharge in model 3 occurrs when the voltage value is zero until reach the maximum voltage and it is continued until the voltage goes to the minimum and it returns to zero. After the discharge event, the voltage drops and electrical discharge is not easy to redischarge for periode of 20 us . When discharge occurs, the discharge current pulse rises to a maximum value of 800 mA. The release of this charge indicates that the ozone generator for model 3 is suffering micro discharge which reacts oxygen to form ozone gas. From the results of this current measurement, it can be seen that the plasma developed is not continuous which follows the release of the charge from this ozone generator.

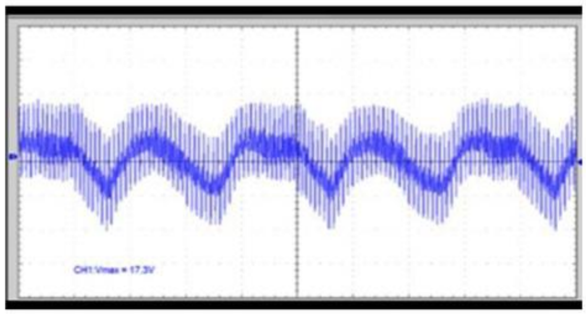


Figure 9a. High voltage power supply open circuit

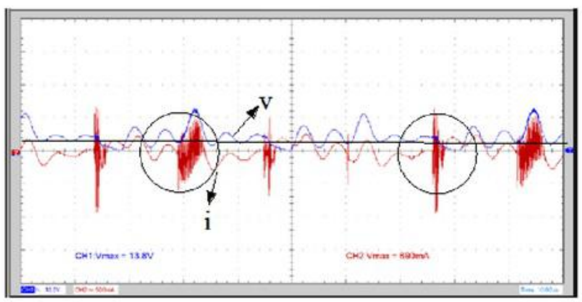


Figure 9b. A permanent magnet under a cathode electrode (Model 1)

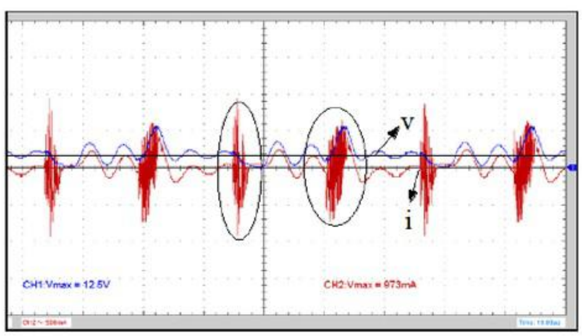


Figure 9c. Two permanent magnets up and bottom electrodes in repulsion condition (Model 2)

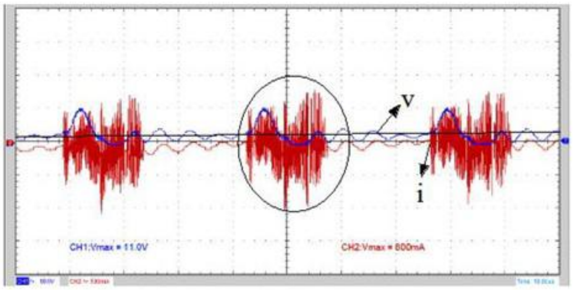


Figure 9d. Two permanent magnets up and bottom electrodes in attraction condition (Model 3)

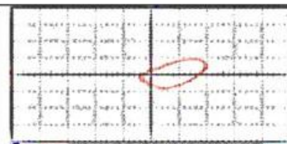
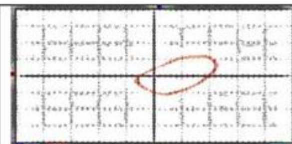
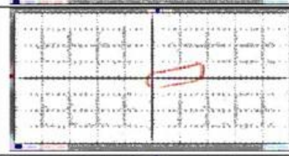
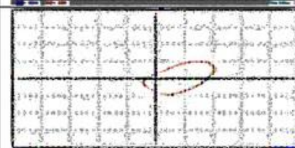
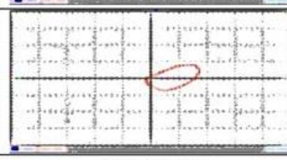
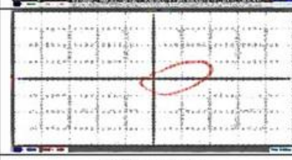
Model 1		
Model 2		
Model 3		
Time	First minute	Fifth minute

Figure 10. Lissajous diagram for all models of DBD

The measurements shown in the Lissajous diagram (figure 10) were carried out using the Sawyer-Tower circuit with a capacitor value of 0.01uF. The voltage versus electric charge graph gives different areas of the Lissajous area. On a 1-minute discharge condition it appears that the lissajous area for all models is slightly different. The area of lissajous in model 3 is slightly more significant when compared to the area in models 1 and 2. The area of the lissajous model 2 is the smallest area compared to other models. However, after a 5-minute discharge, the lissajous area for all models expanded. The area of the lissajous model 3 is slightly smaller than the models 1 and 2. The area of lissajous in model 2 is the largest area compared to models 1 and 3. It is seen that the effect of the position of the permanent magnet parallel to the anode and cathode electrodes on the area of the lissajou (discahrge energy) is not very significant. For further research, it is necessary to place a permanent magnet perpendicular to the anode and cathode electrodes. The accumulation of electric and magnetic fields (BxE) is predicted to have a different impact on the Dielectric Barrier Discharge.

c. Ozone Production

Ozone measurement using a gas analyzer is shown in figure 11 below. The results of the comparison of ozone concentrations produced for all models are given in figure 12. When the ozone generator starts operating in a range of 1 minute, all models suffer a significant increase to generate ozone gas. It can be seen in Figure 5.19, model 1 produces ozone at 98.3 ppm and model 2 produces ozone gas at 135 ppm and model 3 produces ozone to 111 ppm. For this period, it is seen that the generator ozone for model 2 is higher than models 1 and 3. And also the generator ozone for model 3 produces ozone gas higher than model 2. In the period from 1^{st} minute to 5^{th} minute, ozone generator for model 1 is more likely to remain stable in producing ozone gas until the gas concentration value reaches 110ppm. However, the generator ozone for model 2 is gradually up to a value of 162 ppm. Furthermore, the generator ozone for model 3 generates ozone gas which rises sharply until its concentration reaches 207 ppm. Here, it can be seen that the ozone concentration produced from model 3 is higher than that of models 2 and 1. Model 2 also produces higher ozone concentrations than model 1. By looking at the maximum current pattern at discharge, it can be concluded that model 3 occurs current pulses more than models 2 and 1 which is indicated that there is a more ionic discharge that can increase the ionization process on oxygen which further it will produce more ozone gas than model 1 and 2. The effect of induction of ring permanent magnet with attractive conditions is the new thing to improve the performance of ozone generators.

Figure 11. Ozone measurement with a gas analyzer.

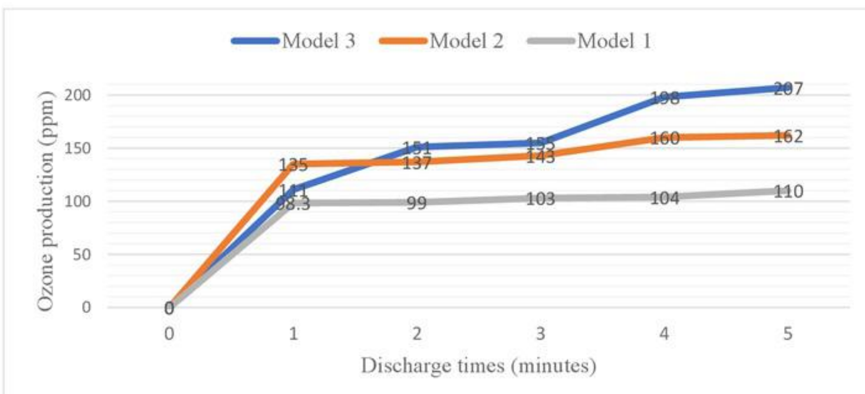


Figure 12. Comparison of ozone concentrations produced for all models

Model 3 has the velocity to produce ozone at an average of 41.4 ppm per minute. While models 1 and 2 produce ozone with an average of 22 ppm per minute and 32.4 ppm per minute, respectively. It is seen that model 3 is faster than models 1 and 2 in producing ozone. While the model 1 is the slowest in producing ozone.

4. Conclusions

This study has succeeded in showing the performance of an ozone generator by using permanent magnet beans as an anode electrode and induced with a permanent magnet ring with three models of the position of the permanent magnet. From the experiments on the three models, it can be concluded that model 3 with the position of the permanent magnet ring above the anode electrode and under the cathode electrode with attracting each other produces more ozone in a 5 minutes period compared to models 1 and 2, respectively. The model 3 is faster to generate the ozone gas with a value of 41.4 ppm per minute. Model 3 also inflows many discharge current pulses which was indicated that there is a lot of electrical discharge in the gap to convert oxygen atoms to ozone gas. From the results of plasma shots that occur in the gap between electrode and dielectric, it can be seen that model 3 produces a plasma with a lower light intensity than models 1 and 2. This can be proven by plasma images of inverted images that model 3 has fewer black areas compared to models 1 and 2. The effect of the position of the permanent magnet is clearly visible in the performance of the ozone generator under attractive condition. It can produce more ozone gas. The addition of permanent magnet beans as anode electrodes is new in the study of high voltage plasma.

5. Acknowledgment

We thank to LPPM for the financial support through Penelitian Percepatan Inovasi DIPA UNRI 2019

6. Refrences

1. W. Siemens, "Ueber die elektrostatische Induction und die erzögerung des Stroms in Flaschendrähten," Poggendorffs Ann. Phys. Chem., vol. 102, pp. 66-122, 1857 (in German).
2. U. Kogelshatz, "Dielectric-barrier Discharges: Their History, Discharge Physics, and Industrial Applications," Plasma Chem. Plasma Process, vol. 33, pp. 1-46, 2003.
3. Y. Nomoto, O. Toshikazu, K. Seiji and A. Takayoshi," improvement of ozone yield by a silentsurface hybrid discharge ozonizer," IEEE. Trans. Ind. Appl., vol. 31, pp. 1458-1462, 1995.
4. N. Zouzou, C. Agbangla, E. Moreau, and G. Touchard, "Diesel Particle Treatment Using a Surface Dielectric Barrier Discharge." IEEE Trans. Plasma Sci., vol. 36, pp. 1354–1365, 2008.
5. Nasruddin, Indri Kartika Putri, Sodiq Kamal,Heni Setyowati Esti, Rahayu, Heni Lutfiyati, Prasojo Pribadi, Tiara Mega Kusuma, Zaenul Muhlisin, Muhammad Nur, Laela Hayu Nurani, BudiSantosa, Tatsuo Ishijima, Toshio Nakatani, "Evaluation the effectiveness of combinative treatment of cold plasma jet, Indonesian honey, and micro-well dressing to accelerate wound healing", Clinical Plasma Medicine, Volumes 5–6,Pages 14-25, June 2017,
6. N. Osawa, T. Suetomi, Y. Hafuka, T, Shuha, Y. Yoshioka, R. Hanaoka, "Investigation on reactor configuration of non-thermal plasma catalityc hybrid method for NOx removal of diesel engine exhaust", International Journal of Plasma and Enviromental Science and Technology, Vol.6, No.2, September 2012.
7. K. Shimizu, S. Muramatsu, T. Sonoda, and M. Blajan, "Water treatment by low voltage discharge in water", International Journal of Plasma and Enviromental Science and Technology, Vol.4, No.1, March 2010.
8. Pekárek "Non-Thermal Plasma Ozone Generation ", Acta Polytechnica Vol. 43 No. 6/2003
9. V. Golota, B dolin, V. Karas, I. Paschenko, S. Pugach, A. Yakovlev, Proc. 16th Int. Symp. on Plasma Chemistry ly, 2003)
10. S. Pekárek" DC corona discharge ozone production enhanced by magnetic field", Eur. Phys. J. D 56, 91–98 (2010) DOI: 10.1140/epjd/e2009-00276-4.
11. K. Nassour *et al.*, "Comparative experimental analysis of ozone generation between surface and volume DBD generators," in *IEEE Transactions on Dielectrics and Electrical Insulation*, vol. 25, no. 2, pp. 428-434, April 2018. doi: 10.1109/TDEI.2017.006600
12. Y. Nakata, R. Mabuchi, K. Teranishi and N. Shimomura, "Effect of small-diameter coaxial reactors on ozone production using nanosecond pulsed power," in *IEEE Transactions on Dielectrics and Electrical Insulation*, vol. 20, no. 4, pp. 1146-1152, August 2013. doi: 10.1109/TDEI.2013.6571429
13. I. Chalmers, L. Zanella, S. J. MacGregor, and I. A. Wray, "Ozone generation by pulsed corona discharge in a wire cylinder arrangement", IEEE Colloquium Digest, Vol.29, pp.1-4, 1994.
14. H. Akiyama, Y. Miyahara, J. Samaranayake, and S. Katsuki, "Ozonizer using pulsed power: Recent Development of ozonizer", J. Plasma and Fusion Research, Vol. 74, No. 10, pp. 1139-1143, 1998
15. K. Takaki, I. Yagi, T. Fujiwara and T. Go, "Influence of circuit parameter on ozone synthesis using inductive energy storage system pulsed power generator," in *IEEE Transactions on Dielectrics and Electrical Insulation*, vol. 18, no. 5, pp. 1752-1758, October 2011. doi: 10.1109/TDEI.2011.6032847
16. Waluyo, Syahrial, Sigit Nugraha and Yudhi Permana JR" Prototype Design and Analysis of Miniature Pulse Discharge Current Generator on Various Burdens", International Journal on Electrical Engineering and Informatics - Volume 8, Number 3, September 2016
17. Fri Murdiya, Febrizal Febrizal, Amun Amri," The performance of surface barrier discharge in magnetic field driven by half bridge series resonance converter", Journal of Mechatronics, Electrical Power, and Vehicular Technology, Vol.8, No.2, pp.95-102, Dec. 2017.
18. J.Y Park , G. H. Kim , J. D. Kim , H.S. Koh, D.C. Lee" NOx Removal Using DC Corona Discharge with Magnetic Field" Combustion Science and Technology, Vol. 133 Issue 1-3, pp. 65-77, Taylor & Francis, 1998
19. Fri Murdiya, Febrizal, "The performance surface barrier discharge in magnetic field driven by series resonance converter", 2017 International Conference on Electrical Engineering and Informatics (ICEEI), Langkawi Malaysia,25-27 Nov. 2017.
20. Stanislav Pekárek "Experimental Study of Nitrogen Oxides and Ozone Generation by Corona-Like Dielectric Barrier Discharge with Airflow in a Magnetic Field" Plasma Chem Plasma Process, vol. 37, pp. 1313–1330, Springer, 2017.
21. Liu, H. Qi, Z. Fan, C.S. Ren, " The impacts of magnetic field on repetitive nanosecond pulsed dielectric
22. Jodzis S, Patkowski (2017) J Electrostat 85:43–51. https://doi.org/10.1016/j.elstat.2016.12.009
23. Stanislav Pekárek, "Experimental Study of Pulse Polarity and Magnetic Field on Ozone Production of the Dielectric Barrier Discharge in Air", Plasma Chemistry and Plasma Processing, Volume 38, Issue 5, pp 1081–1093, September 2018https://doi.org/10.1007/s11090-018-9914-2

The effect of the magnetic field on an ozone generator fed by a non-sinusoidal half-bridge resonance inverter

ORIGINALITY REPORT

22%	15%	19%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Fri Murdiya, Budhi Anto, Eddy Hamdani, Suwitno, Edy Evrianto, Amun Amri. "Barrier Discharge In Magnetic Field: The Effect Of Magnet Position Induced Discharge In The Gap", 2018 2nd International Conference on Electrical Engineering and Informatics (ICon EEI), 2018 Publication	7%
2	Kamel Nassour, Mostefa Brahami, Amar Tilmatine, Said Nemmich, Farid Miloua, Nadia Ramdani, Noureddine Zouzou. "Comparative experimental analysis of ozone generation between surface and volume DBD generators", IEEE Transactions on Dielectrics and Electrical Insulation, 2018 Publication	2%
3	link.springer.com Internet Source	1%
4	Ryo Mabuchi, Yuki Nakata, Tatsuya Kageyama, Kenji Teranishi, Naoyuki Shimomura.	1%

"Investigation of ozone production using nanosecond pulsed power to increase ozone concentration", 2012 IEEE International Power Modulator and High Voltage Conference (IPMHVC), 2012
Publication

5	onlinelibrary.wiley.com Internet Source	1 %
6	media.neliti.com Internet Source	1 %
7	Submitted to Universiti Malaysia Pahang Student Paper	1 %
8	Bonaldo, Jakson P., José A. Pomilio, and Edson A. Vendrusculo. "Power Equalization Techniques for Three-Phase VSI-driven Single-Phase Ozone Generators", Ozone Science and Engineering, 2014. Publication	1 %
9	repo.lib.tokushima-u.ac.jp Internet Source	1 %
10	Stanislav Pekárek. "Experimental Study of Pulse Polarity and Magnetic Field on Ozone Production of the Dielectric Barrier Discharge in Air", Plasma Chemistry and Plasma Processing, 2018 Publication	1 %

11	Shuqun Wu, Fei Wu, Xueyuan Liu, Wen Chen, Chang Liu, Chaohai Zhang. "Investigation on the characteristics of an atmospheric-pressure microplasma plume confined inside a long capillary tube", Plasma Science and Technology, 2018 Publication	<1%
12	mevjournal.com Internet Source	<1%
13	Submitted to Ohio State University Student Paper	<1%
14	Submitted to Universiti Teknologi MARA Student Paper	<1%
15	www.ijeei.org Internet Source	<1%
16	Submitted to Queensland University of Technology Student Paper	<1%
17	www.epjap.org Internet Source	<1%
18	Submitted to University of Strathclyde Student Paper	<1%
19	S. Pekárek. "DC corona discharge ozone production enhanced by magnetic field", The European Physical Journal D, 11/06/2009	<1%

Publication

20	ijeei.org Internet Source	<1%
21	Fri Murdiya, Febrizal Febrizal, Amun Amri. "The performance of surface barrier discharge in magnetic field driven by half bridge series resonance converter", Journal of Mechatronics, Electrical Power, and Vehicular Technology, 2017 Publication	<1%
22	Komalasari, S P Utami, M I Fermi, Y Aziz, R S Irianti. "Corrosion control of carbon steel using inhibitor of banana peel extract in acid diluted solutions", IOP Conference Series: Materials Science and Engineering, 2018 Publication	<1%
23	kyutech.repo.nii.ac.jp Internet Source	<1%
24	dspace.lboro.ac.uk Internet Source	<1%
25	watermark.silverchair.com Internet Source	<1%
26	Hazlee Illias, Teo Soon Yuan, Ab Halim Abu Bakar, Hazlie Mokhlis, George Chen, Paul L. Lewin. "Partial discharge patterns in high voltage insulation", 2012 IEEE International	<1%

Conference on Power and Energy (PECon), 2012
Publication

27	Submitted to University of Newcastle upon Tyne Student Paper	<1%
28	Submitted to Edith Cowan University Student Paper	<1%
29	Kamel Nassour, Mostefa Brahami, Said Nemmich, Nacera Hammadi, Noureddine Zouzou, Amar Tilmatine. "New Hybrid Surface–Volume Dielectric Barrier Discharge Reactor for Ozone Generation", IEEE Transactions on Industry Applications, 2017 Publication	<1%
30	Submitted to Universiti Teknologi Malaysia Student Paper	<1%
31	Bin Xu, Yifang Zhu. "Quantitative Analysis of the Parameters Affecting In-Cabin to On-Roadway (I/O) Ultrafine Particle Concentration Ratios", Aerosol Science and Technology, 2009 Publication	<1%
32	pub2.db.tokushima-u.ac.jp Internet Source	<1%
33	Submitted to Chungnam National University Student Paper	<1%

34	Shuqun WU, Fei WU, Xueyuan LIU, Wen CHEN, Chang LIU, Chaohai ZHANG. "Investigation on the characteristics of an atmospheric-pressure microplasma plume confined inside a long capillary tube", Plasma Science and Technology, 2018 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		