DOI: 10.34185/1991-7848.itmm.2023.01.090

TECHNOLOGIES FOR POWERING HIGH-PERFORMANCE OZONE GENERATORS: TRENDS AND PERSPECTIVES

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Abstract. Ozone generators are devices that produce ozone gas for various applications, such as water treatment, air purification, and medical sterilization. The performance of ozone generators largely depends on the technology used to power them. This article provides an overview of the latest trends and perspectives in technologies for powering high-performance ozone generators. We discuss various power sources, such as corona discharge, ultraviolet radiation, and electrolysis, and their advantages and limitations. We also review recent developments in power electronics and control systems for ozone generators, including pulse-width modulation, frequency modulation, and feedback control. Finally, we discuss future directions for research and development in ozone generator technology, such as the use of renewable energy sources and the integration of ozone generation with other technologies for sustainable water and air treatment.

In recent years, there has been significant progress in the development of high-performance ozone generators using advanced power electronics and control systems. The most common methods of ozone generation in the industry are Corona discharge, Ultraviolet radiation, and Electrolysis. Each method has its advantages and limitations, such as the efficiency, cost, and safety of the process. Corona discharge is the most commonly used method for generating ozone in industrial applications [1]. This process involves a high-voltage electrical discharge being passed through a gas, typically air or oxygen, causing the molecules in the gas to ionize and generate ozone. The efficiency of the corona discharge method can be affected by various factors, such as the humidity and temperature of the gas, the strength of the electrical field, and the design of the discharge chamber. However, corona discharge remains a popular method for generating ozone due to its relatively low cost and high efficiency.

Ultraviolet (UV) radiation is another commonly used method for ozone generation in industry. This method involves exposing oxygen to UV light with a wavelength of 185 nanometers, which breaks down the oxygen molecules and forms ozone [2]. The advantage of UV radiation is that it does not produce unwanted by-products, making it a cleaner and safer method for ozone generation. However, the efficiency of the process is relatively low, and high concentrations of ozone can be difficult to achieve [2]. To improve the overall efficiency of ozone generation, UV radiation is often used in combination with other methods, such as corona discharge or electrolysis [3].

Electrolysis is a third common method for ozone generation in industrial applications [4]. It involves the use of an electric current to decompose water molecules into oxygen and hydrogen gas, and then react the oxygen with more oxygen molecules to produce ozone. It involves the use of an electric current to split water molecules into hydrogen and oxygen, which can then react to form ozone [5]. However, the process requires high-purity water or special electrolyte and is sensitive to impurities, which can affect the efficiency of the process [4]. Additionally, electrolysis can only be used to generate low to moderate concentrations of ozone, which limits its application in certain industrial processes [5]. Despite these limitations, electrolysis remains a viable method for ozone generation in certain applications, such as water treatment and semiconductor manufacturing [4].

Power electronics and control systems are essential components of ozone generators, playing a critical role in their performance and efficiency [6]. They are responsible for converting the incoming electrical power into a form suitable for ozone generation and regulating the power output of the generator. Pulse-width modulation (PWM) and frequency modulation (FM) are two commonly used methods for controlling the power output of ozone generators [7]. By using these techniques, the power output of the generator can be varied to produce ozone at different concentrations.

Pulse-width modulation (PWM) is a widely used method for controlling the power output of ozone generators. PWM works by varying the duty cycle of the electrical pulse used to drive the ozone generation process. The duty cycle refers to the ratio of the pulse width (the time the pulse is on) to the period of the pulse (the total time of one cycle) [9]. The frequency of the electrical pulse is typically in the range of a few kilohertz to several tens of kilohertz. By adjusting the duty cycle of the electrical pulse, the power output and ozone concentration can be optimized for a particular application. PWM is commonly used in high-frequency inverters that drive the ozone generation process by converting DC voltage to AC voltage. One advantage of PWM in ozone generation is that it allows for precise control of the power output and ozone concentration. Additionally, PWM is a relatively simple and low-cost method of controlling the power output of an ozone generator. However, PWM is less efficient than other methods, such as frequency modulation, at higher power levels.

Frequency modulation is another technique that is commonly used to control the power output of ozone generators. This technique involves varying the frequency of the electrical signal used to drive the ozone generation process. By varying the frequency of the signal, the power output of the generator can be controlled to produce ozone at different concentrations. In the ozone generation process, FM is commonly used in low-frequency inverters that convert DC voltage to AC voltage, which is used to drive the ozone generation process. The frequency of the electrical signal is typically in the range of a few hundred hertz to a few kilohertz. FM is advantageous in the ozone generation process because it can provide a higher level of precision compared to other techniques such as pulse-width modulation (PWM). By varying the frequency of the electrical signal, the power output of the generator can be adjusted in smaller increments, allowing for more precise control over the concentration of ozone produced [7]. One disadvantage of FM is that it can be more complex to implement than other techniques, such as PWM. This is because FM requires a more complex control system that can accurately vary the frequency of the electrical signal based on the desired power output. Despite this complexity, FM is still commonly used in ozone generators, especially in applications where precise control over the concentration of ozone is required.

Feedback control is an essential aspect of power electronics and control systems used in ozone generators [8]. It involves monitoring the performance of the generator and adjusting the power output based on various parameters, such as the concentration of ozone, the temperature of the generator, and the humidity of the air. By using feedback control, the performance and efficiency of the generator can be optimized to produce ozone at the desired concentration and with minimal energy input. Feedback control is typically achieved through a closed-loop system that continuously monitors the performance of the generator and adjusts the power output accordingly.

Control systems play a critical role in the performance and efficiency of ozone generators [6]. In general, a control system is used to monitor the concentration of ozone in the output gas stream and adjust the power output of the generator to maintain a desired level of ozone concentration. There are several types of control systems used in ozone generators, including proportional-integral-derivative (PID) controllers, fuzzy logic controllers, and artificial neural network (ANN) controllers.

PID controllers are a common type of control system used in ozone generators. They use feedback control to adjust the power output of the generator based on the difference between the actual and desired ozone concentration levels. The controller calculates an error signal based on the difference between the setpoint and the measured concentration of ozone and uses this signal to adjust the power output of the generator. PID controllers are widely used because they are simple and effective, and can be easily tuned to achieve optimal performance.

Fuzzy logic controllers are another type of control system used in ozone generators. They use a set of rules to determine the appropriate power output of the generator based on the measured ozone concentration. Fuzzy logic controllers are particularly useful in applications where the ozone concentration is subject to large fluctuations, as they can adapt to changes in the input signal and provide stable control. ANN controllers are a newer type of control system that use artificial neural networks to learn and adapt to changes in the input signal. They are particularly useful in complex applications where the relationship between the input and output signals is nonlinear and difficult to model mathematically.

Overall, control systems are essential for optimizing the performance of ozone generators and ensuring that they produce the desired concentration of ozone. The type of control system used will depend on the specific application and requirements of the generator.

Future Directions. Future research and development in ozone generator technology will focus on improving the efficiency and sustainability of the process. The use of renewable energy sources, such as solar and wind power, for powering ozone generators is an emerging trend that can reduce the carbon footprint of the process. Integration of ozone generation with other technologies, such as membrane filtration and activated carbon adsorption, can also improve the overall performance of water and air treatment systems.

Conclusion. In summary, power electronics and control systems are essential to the performance and efficiency of ozone generators. Technologies for powering high-performance ozone generators have advanced significantly in recent years, with new developments in power electronics and control systems. The choice of power source and control method depends on the specific application and requirements of the ozone generator. Future research and development in ozone generator technology will focus on improving the efficiency and sustainability of the process, with the use of renewable energy sources and integration with other technologies.

Keywords: ozone generation, corona discharge, ultraviolet radiation, electrolysis, control systems, power electronics.

References

1. Zhou, X., Zhao, Y., Wang, Y., & Wu, Y. (2019). Research progress in high-performance ozone generator. Journal of Environmental Sciences, 78, 1-11.

2. Wu, C., Senthilkumar, S., & Zou, S. (2020). UV - Ozone Cleaning of Graphene Oxide: Mechanisms and Applications. ChemPhysChem, 21(3), 263-270.

3. Oka, T., & Okumura, K. (2018). Efficiency improvement of UV/ozone treatment by introduction of a corona discharge system. Journal of hazardous materials, 347, 386-394.

4. B. Gholivand Khajeh and M. Ziaei, "Ozone generation using the electrolysis method: a review," Chem. Eng. Commun., vol. 206, no. 11, pp. 1476-1491, 2019.

5. J. Fang, T. C. W. Mak and H. K. H. Choy, "A review of ozone generation technologies," Appl. Sci., vol. 8, no. 12, p. 2425, 2018.

6. Park, "Development of ozone generator with high efficiency power supply and control system," IEEE Transactions on Plasma Science, vol. 36, no. 5, pp. 2379-2384, Oct. 2008.

7. J. K. Kim and H. Kim, "Power control of ozone generators using frequency modulation," IEEE Transactions on Power Electronics, vol. 19, no. 3, pp. 765-773, May 2004.

8. T. Nakamura, T. Takada, and K. Shikama, "High-frequency ozone generator using PWM power supply," Proceedings of 2012 International Power Electronics Conference - ECCE Asia, pp. 3193-3197, May 2012.

9. T. Jiang, X. Chen, and L. Zhang, "Research on control system of high concentration ozone generator based on PLC," Proceedings of 2011 International Conference on Electrical and Control Engineering, pp. 6347-6350, Sep. 2011.