Fuzzy Logic System Research for Improved Efficiency of Electric Ozonators

Sorin Radu Budu

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Budu Sorin Radu [1][0000-0001-8342-9328]

Technical University of Cluj-Napoca

Abstract.

Fuzzy Logic (FL) was conceived as a better method for sorting and handling data but it has been proven to be a excellent choice for many control system applications since it mimics human mind logic control. The author had apllied *FL* in order to simulate and determine higher amounts by electrical method of ozone generation, at high frequencies, in order to determine the improvement of the ozone generation efficiency, for sterilization of wastewaters, medical equipment and pathogens (viruses and bacteria, including Covid-19).

Keywords: fuzzy logic, simulation, ozone generation, voltage waveform.

1. Introduction

Purification and treatment of wastewater with ozone in recent years has become one of the most modern and attractive ecological methods of industrial and domestic wastewater treatment [9].

Due to the strong oxidizing effect of ozone and its non-toxicity, purification and treatment of water with ozone successfully replaces at present the classic methods that use chemical substances such as chlorine and fluoride, but which have long been shown to have severe carcinogenic and allergenic effects on the human body [13].

Improvement of the ozone synthesis process has known the following research-development directions:

- increase in the amount of ozone generated by increasing the supply voltage amplitude;
- use of alternating current voltage and increase its frequency (from 50 Hz to 10 kHz);
- generation of silent electrical discharges (without arc or spark discharges) and use of dielectric barriers;
- combined action of ozone for water treatment: ozone + intense electric fields, ozone + ultraviolet radiation, ozone + classical (chemical) treatment methods.

At present, large-scale industrial applications of ozone are aimed at purifying and treating air, wastewater, plastic, bleaching textiles, paper, waste sevage. There has also been an explosive development in the use of ozone in medicine in the recently ten years.

The topic of the paper is in line with current global research trends outlined above and contributes to increasing the concentration of generated ozone and reducing specific energy consumption in laboratory and industrial electric ozonators by using the **Fuzzy Logic** (FL) system.

2. Materials and experimental methods

The most used inference mechanisms are: **Mamdani and Sugeno.** The algorithm used by the author for fuzzification is of the MAMDANI type. FL algorithms are applied to input variables.

Each input variable is associated with a function (algorithm) that best characterizes the evolution of the variable during the process.

The “waveform” operator indicates the influence of this functions (sine, triangular, Gaussian, trapezoidal, etc.) in correlation with its phase ($0 \div 180^o$), and determine the final fuzzification result.

Also, the voltage waveforms used for the simulation are associated with each half-alternation.The Fuzzy Logic system is very effective, providing accurate results and after physical application in practice, the obtained results are surprisingly precise. In the paper the author had applied FL algorithms to a Gauss type voltage waveform.

Fuzzification algorithms ensure the analysis and interpolation of data contained in the set of input variables. These algorithms are in fact graphical representations of the degree of influence of each input variable against the other input variables and the effect on the conclusion. A degree of influence is associated with each input variable, and the algorithms define and scan the loops of interoperability and interference between inputs and ultimately determine the output response.

3. Results.

The window for defining the set of input variables is depicted in **Figure 1**.

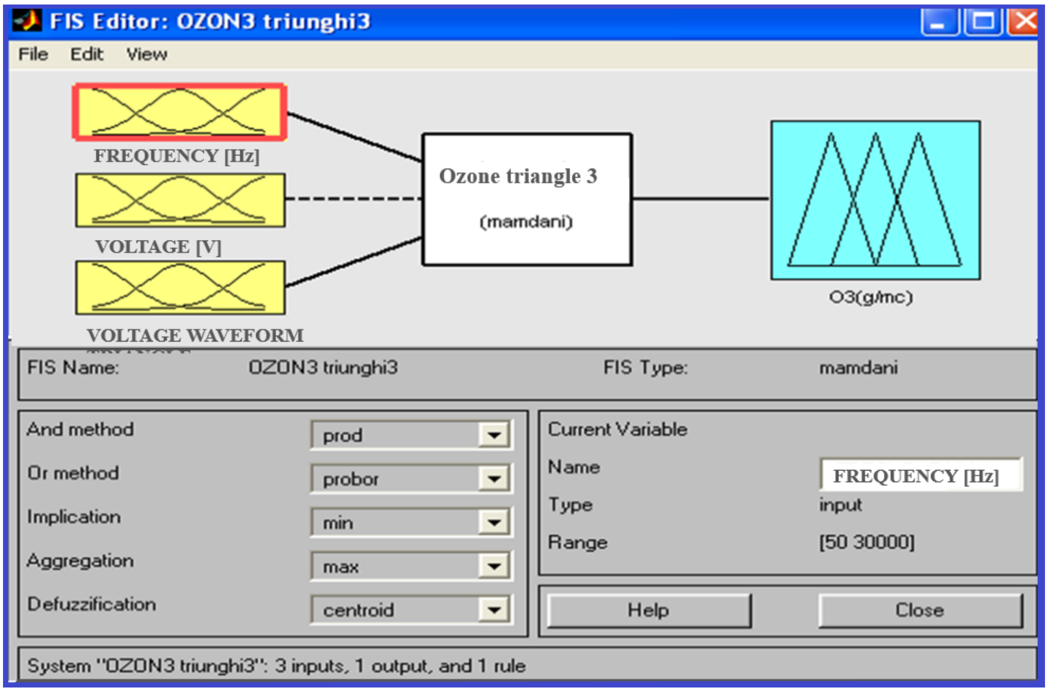


Figure 1. *Window for defining the set of input variables, the fuzzification method (mamdani), the range of values traversed by them, the inference, aggregation and defuzzification operators for a triangular waveform.*

The author had used a Gauss type waveform (**Figure 2a**). The simulation results (experimental conditions f = 50 Hz ÷ 30 kHz, U = 7 ÷ 50 kV) indicate a maximum generated concentration of 259 g O_3/m^3 (**Figure 2b**) and a volumetric representation of ozone concentration - voltage - frequency according to **Figure 2c**.

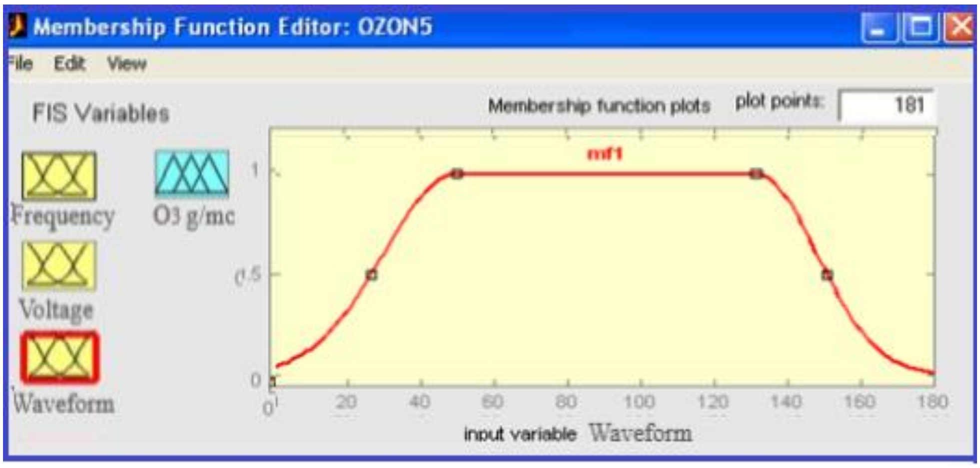


Figure 2a. *Simulation of Gauss type high voltage waveform, with variable frequency and voltage level.*

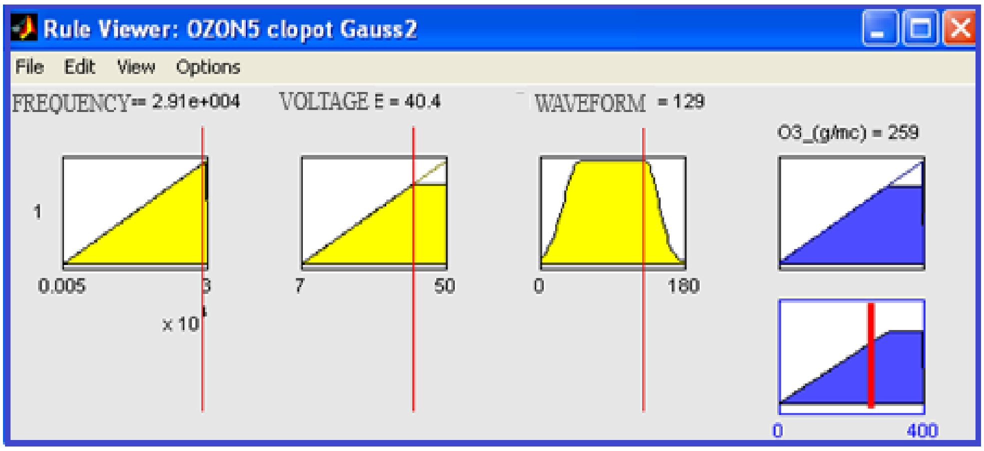
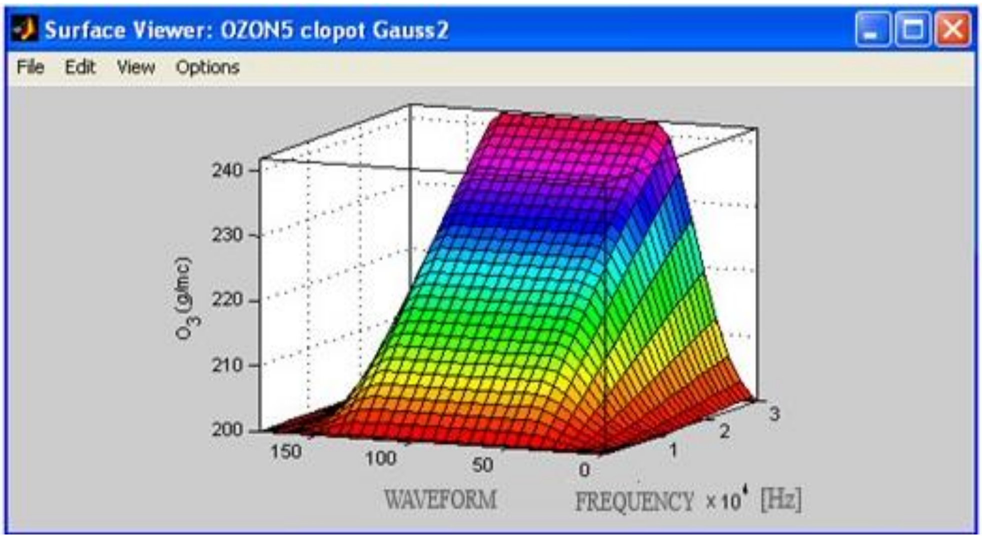


Figure 2b. *Applied range and evolution of the voltage frequency, the peak and the limits of maximum efficiency of voltage, for a Gauss type waveform average and quantity of ozone generation (O_3g/mc).*



(c)

Figure 2c. *Simulation of the ozone concentration generated as a function Gauss type of the supply voltage; waveform shape (a), U amplitude [kV], frequency [Hz] (b), and its distribution on the range 0 - 180º (c).*

Based on this simulation, a new shape of voltage waveform and a novel type of ozone generator (now in procedure to be patented), was developed by the author, the aim beeing to achieve much higher amount and concentrations of ozone. Experiments carried by the author on a Siemens laboratory ozonator (experimental conditions: ozonator with cylindrical electrodes ($Ø_{outer}$ = 54 mm, $Ø_{inner}$ = 52 mm, glass dielectric barrier g = 0.75 mm, gas used - air, processed gas flow - 2 l/min., U = 10 kV) confirms up to frequencies of 1,000 [Hz] the proportional variation of the concentration of ozone generated reportedto the frequency evolution. After many tests carried on this issue, the author proposes, for frequencies below 1,000 [Hz], an original empirical formula for ozone concentration:

$$Q_{ozone}\,[mgO_3/l] = 0{,}009 \cdot f\ [Hz] \qquad (1)$$

The experimental determined variation of ozone concentration (and consequently of generated ozone reported to the volume) is presented in **Figure 3**:

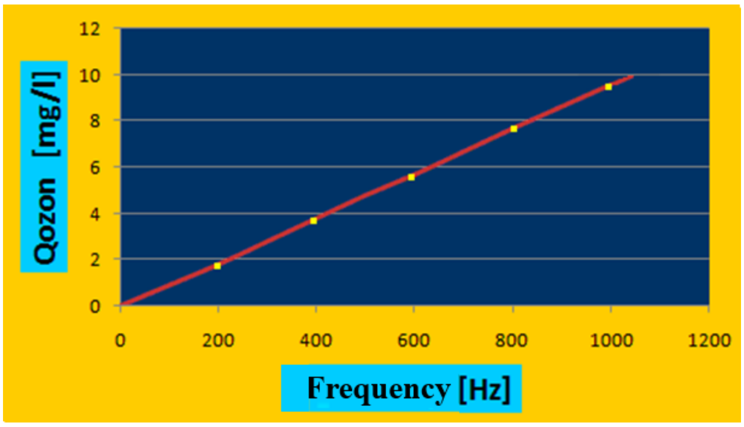


Figure 3. *Variation of the concentration of generated ozone as a function of the supply voltage frequency, at the laboratory tubular ozonator equipped with cylindrical electrodes.*

4. Conclusions

- By using FL system, the necesary time to carry out the scientific activity is strongly reduced and the precision of method determine to get rapid results of research work in comparison with classic methods, so that a lot of preliminary physical, expensive, time and financial consuming resources, are no longer necessary**.**
- Simulation results indicate the need to use voltages with different shapes, high amplitudes and frequencies to obtain increased ozone concentrations.
- The Gauss type voltage waveform provides a higher quantity ozone than the sigmoid shape of the voltage.

References:

1. Volovenco, C. - Fuzzy Systems. Theory and Applications, *Editure IntechOpen*. **2022**, EAN**:** 9781839622915, **ISBN**: 1839622911**,** Libristo Code: 38621567.
2. The Efficiency Increase of Equipment for Treatment in High Intense Electric Fields with Abundant Ozone Generation. *International Conference on Ozone & Related Oxidants in: Advanced Treatment of Water for Human Health and Environment Protection.* **2008**, Brussels, Belgium, May 15th – 16th.