Research upon Optimizing the Performance of Electric Ozonators by Using the Fuzzy Logic System

Sorin Radu Budu

October 31, 2022

Research upon Optimizing the Performance of Electric Ozonators by using the Fuzzy Logic System

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

Technical University of Cluj-Napoca[2]

Abstract

The concept of Fuzzy Logic (*FL*) works not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. This method focuses on what the system should do, rather than trying to understand how it works. FL requires some numerical parameters în order to operate such as what is considered significant error and significant rate-of-change-of-error. The author had apllied *FL* in order to simulate and determine higher generated quantities of ozone by electrical methods. The main objective of this research is to determine new possibilities to increase of the ozone generated quantities and consequently the concentrations of ozone.

Keywords: fuzzy-logic, simulation, higher ozone quantity, new voltagewaveform.

1. Introduction

Climate had changed in the last two decades and the large-scale water pollution with a multitude of chemical and microbiological pollutants, due to the industrial development of the last century, have imposed at world level the ecological use of non-polluting technologies, for water and air treatment, including their treatment with ozone. From this perspective, the field addressed in this paper is very topical and has immediate practical applicability.

Industrially, ozone can be synthesized by electric discharges (arch discharges, spark, corona fields) and by thermal, electrochemical, photochemical processes, under the action of particle jets and by electrolysis. The most advantageous method at present, although the efficiency of ozone generation is still low (17 ÷ 20%), is that by silent electric discharges in corona field [17].

Intensity of electric current widespread use of ozone is limited due to the high specific energy consumption (W_{ozone}) required to generate it (on average 17 ÷ 20 kWh/kg O_3), although the fields of application of ozone are very varied [18].

The modern used method for the industrial production of ozone is by electric discharges, and in modern industrial electric ozonators the electric discharges in corona field have the most important share [1,2,19].

2. Materials and experimental methods

An fuzzy control system *(FL*) can be interpreted as an interpolation mechanism. The advantage of input-output transfer by interpolation leads to obtaining controllers that interpolate these actions according to the controller input. The basic concept of the method is to focus on what a system should do, not necessarily to understand how it works. The *FL* method operates with input ("variables") and output ("conclusions") sets and a compilation block ("fuzzification") that manages and interpolates based on several logical and mathematical operators, parameters that define all quantities contained in the set of input variables. The result are defuzzfied and provides the range and dynamics in which the output quantity is manifested [12].

The inference mechanisms are of two types, **Mamdani and Sugeno**, and the operating logic and mathematical algorithms used in the simulations are those imposed by the software manufacturer, Matlab Fuzzy Logic Tools [23]. The algorithm used by the author for fuzzification is of the MAMDANI type.

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.

Several types of functions (algorithms) are used, applied to input variables, but the most commonly used are the functions: triangular, bell (Gaussian), trapezoidal, sinusoidal, exponential, sigmoid, probabilistic, logical operator type (AND, OR). Additional functions of higher complexity may be **magnitude**, **width** (base of the function), **centre point** (centre point of the waveform of the function, centre of gravity), **overlap** (up to 50% of the wavelength).

Each input variable is associated with a function (algorithm) that best characterizes the evolution of the variable during the process. The system works on the principles of working with logical operators such as: **IF** X **AND** Y **THEN** Z or **IF** X **OR** Y **THEN** Z. The result is decompiled (defuzzified), thus obtaining the response ("conclusion").

By this means the author had simulated, developed, tested and further implemented the results obtained, in order to achieve higher quantities and concentrations of ozone. A new shape of the voltage waveform and an ozonification device working at high frequecies (25 kV, 15 kHz) was developed, tested in practice by the author and now an patent proposal is in progress.

3. Results.

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

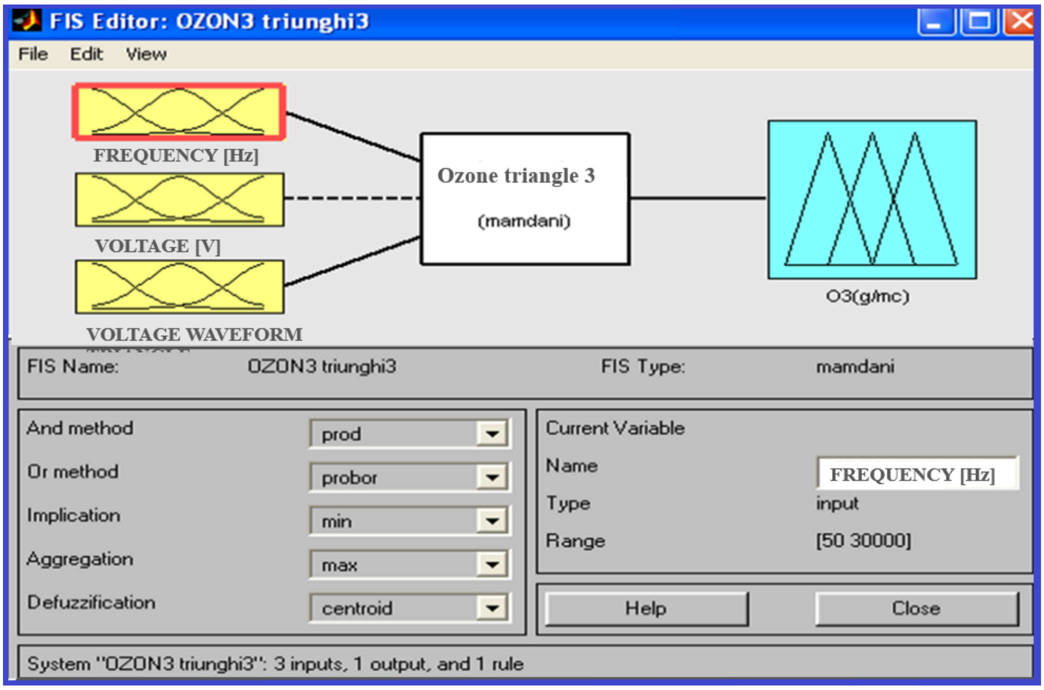

Figure 1. *Window for defining the set of input variables, the fuzzification method (mamdani), the range of values traversed by them, the inference, aggregation and defuzzification operators for a triangular waveform.*

Results of this simulation, in **3d** coordinates, corresponding to the values given to the input simulating values of **O_3** quantities, are presented in **Figure 2 a,b,c.**

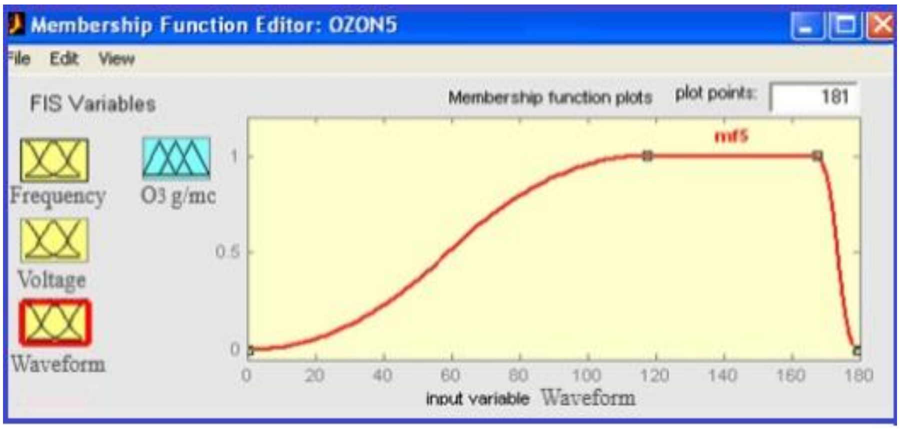

Figure 2a. *Simulation of an original high voltage waveform, with variable frequency (50 Hz ÷ 30 kHz) and voltage level (7 ÷ 50 kV), in order to obtain larger amount of ozone quantities.*

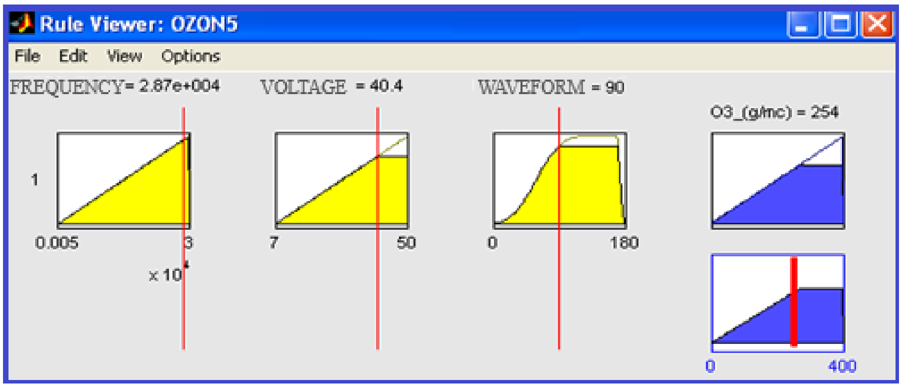

Figure 2b. *Applied range and evolution of the voltage frequency, the peak and the limits of maximum efficiency of voltage, waveform average and quantity of ozone generation (g/mc).*

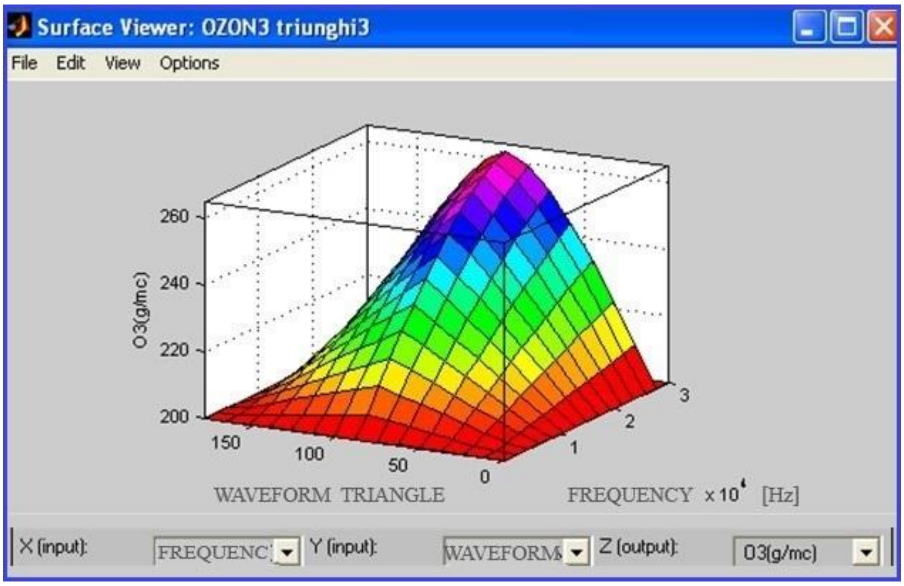

Figure 2c. *Simulation results of the ozone concentration generated as a composed function of the supply voltage waveform triangle shape (a), voltage amplitude [kV], frequency [Hz] (b), and its sigmoid distribution on the range 0 - 180^o (c).*

Experiments were carried by the author on a Siemens type laboratory ozonator. As a result of simulation, a new shape of voltage waveform (**Figure 3**) and a novel type of ozone generator (now in procedure to be patented), was developed by the author.

The areas determined by the extreme limits of the P1131, P1132 parameters indicate, on both half-alternations, the active corona discharge areas where ozone is generated, their area being directly proportionaly to the amount of generated ozone and the P_g absorbed power. The fields corresponding to the P1130, P1133 parameters are the areas where corona discharge does not occur.

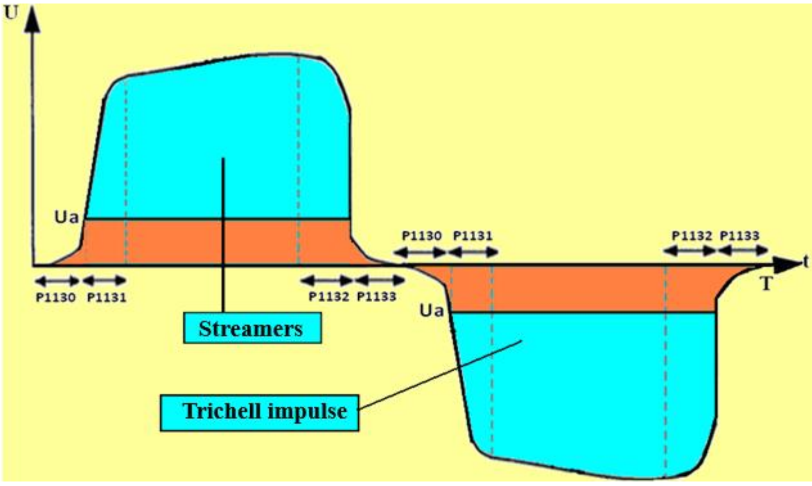

Figure 3. Original waveform with a steep discharge slope in order to increase the concentration of ozone generators.

4. Conclusions

- Through the Fuzzy Logic method, the obtained results are about 30% -50% more precise than through the mathematical methods that use algorithms associated with the mathematical functions that describe the processes [1].
- Results of the simulation by *FL* certify the accurace of the method and also can determine the dependence of the amount of ozone generated according simultaneous to the frequency, supply voltage level, the waveform applied to the ozonator.
- The level and shape of voltage and also the frecquency of applied voltage are extremely important in order to produce large quantities and concentration of ozone.

References

1. Volovenco, C. - Fuzzy Systems. Theory and Applications, *Editure IntechOpen*. **2022**, EAN: 9781839622915**,** ISBN**:** 1839622911, Libristo Code: 38621567.

2. Suărăşan, I., *Budu, S.R***.,** Oros, O. D., Morar, R., Ghizdavu P.S., Ghizdavu,L., Muntean, I. 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.

3. Suărăşan, I., Mudura, M., *Budu, S.R***.**, Oros, D., Mischian, A., Morar, R. Ozone and High Intense Electric Fields – Possible Factors for Wastewater Cleaning. *International Conference on Ozone & Related Oxidants in: Advanced Treatment of Water for Human Health and Environment Protection.* **2008**, Brussels, Belgium, May 15th – 16th.