Electromagnetic Stress Induced by Surface Discharges on Water Film

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***Abstract* – This paper deals with analysis of cold plasma surface discharges used as depollution techniques in order to induce oxidation/ reduction reactions in polluted water, without catalysts involvement. The paper is a statistical assessment of dependency between the electromagnetic stress induced by electrical surface discharges on water films and the distance from the discharge point. The electromagnetic field waves are generated by cold plasma electrochemical reactors surface discharge type.**

Keywords – surface discharge, cold plasma, water film, depollution

I. INTRODUCTION

Modern technologies for water treatment use strong electric field non-thermal plasma for electrochemical reactions initiation. Electric discharges on water lead to the generation of chemical and physical reactions.

As resulted from [1], most of plasma reactors uses for water treatment pulse corona discharges, where the voltages applied to electrodes in diverging geometry have a peaked rise time in a short time. The plasma electrochemical reactors generate electrons, positive ions, negative ions or excited atoms.

In this case of discharge, only the electrons can achieve high energy, while the rest of active species, like ions, will not gain enough energy to induce electrochemical reactions.

While the corona system uses discharges of about 1 J/pulse, the pulsed discharge uses energy around 1 kJ/pulse or higher. For this reason, in the present paper it was performed an analysis based on surface discharge reactor which generates non-thermal plasma (NTP).

Non-thermal plasma is an environmentally friendly procedure whose applications include water treatment for dissolving toxic compounds [2]. The non-thermal plasma technology may also be used to generate molecular compounds in water or to eliminate organic pollutants in liquids [3].

Typical non-thermal plasma reactors have a cylindrical glass tube where are positioned two electrodes, which will allow generating plasma discharge.

II. TESTING CONFIGURATION FOR SURFACE DISCHARGES

In order to achieve plasma treated water, in this paper it was used an electrical discharge reactor supplied from a high voltage pulse source, which produces an electrical air discharge over a water film. In Fig.1 is illustrated the schematic diagram of surface discharge reactor.

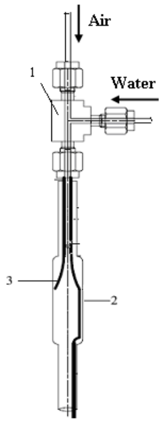

Fig.1. Surface discharge reactor

The high voltage source which supplies the reactor is represented by a fly-back pulse generator, which allows generating electrical discharges in the range (50 ÷500) Hz. By supplying a path for air in reactor's configuration, the water may be drizzled directly into the plasma zone, achieving yield efficiency for active species generation in the water film [4].

Measurements were performed using two type of data acquisition devices, in order to assess a comparison between the plasma discharge radiated fields: LECROY digital oscilloscope and Aaronia SPECTRAN NF 5030 spectrum analyzer, with integrated electric (E) and magnetic (H) field antenna.

SPECTRAN NF 5030 measurement device allows performing professional electromagnetic field data acquisition using a frequency dependant measurement approach.

The spectrum analyzer determines the radiation sources in the surroundings, in our case the radiation source being considered the non thermal plasma discharge. Results of field measurements are real time displayed based on their frequencies and signal strengths.

In the present paper, measurements were conducted over different distances from 20 cm up to 150 cm from the plasma discharge point, in order to assess the field's strengths and its dependence on the frequency and distance from the discharge.

III. ELECTROMAGNETIC STRESS ASSESSMENT

In this paper, the electromagnetic stress is considered to be represented by the electric and magnetic fields radiated from the non thermal plasma discharge, during water treatment process. To generate the electric and magnetic field it was used a cold plasma electrochemical reactors surface discharge type.

In Fig. 2 is presented a cold plasma electrochemical reactor surface discharge type with two main electrodes (E1, E2) that are connected to a pulse high voltage power supply (HVPS) [5].

To acquire the signal of electric and magnetic field generated at different distances from the reactors, it was used a spectrum analyzer or an oscilloscope (OSC).

As it can be noticed in the below figure, the voltage is measured using a high voltage divider (Rd1 and Rd2), while the current is acquired on the shunt resistor (Rsh).

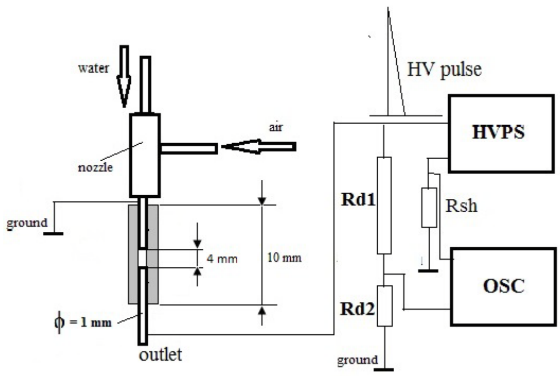

Fig.2. Electrical diagram of cold plasma electrochemical reactor

To achieve the electromagnetic stress propagation over distance, it were generated non thermal plasma discharges and the perturbation was acquired using professional spectrum analyzers. E-field strength was determined from the voltage waveform recordings, with the equation $E=U/d$, where U is the voltage and d is the distance from the discharge.

Fig.3. Reactor's non thermal plasma discharge

The non thermal plasma discharge from the reactor can be observed in Fig. 3.

For each discharge cycle, it will appear electromagnetic perturbations for the electronic devices situated in the proximity of the reactors.

In Fig. 4 it is illustrated the NTP discharge voltage and current spectrum recorded at 20 cm for the Lecroy oscilloscope signal acquisition.

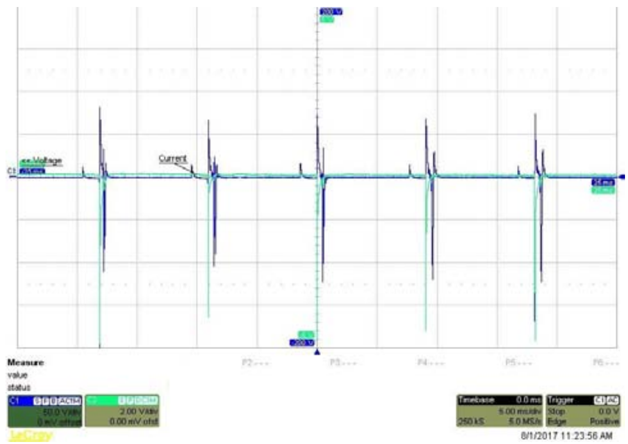

Fig.4 NTP discharge voltage and current spectrum at 20 cm – Lecroy oscilloscope

Electromagnetic perturbations were acquired at frequencies between 50 Hz and 500 Hz, using Aaronia Spectran NF 5030.

In Fig. 5 is presented the electric field spectrum recorded on OX axis. It was considered this axis due to the fact that the non thermal plasma reactor has a cylindrical configuration.

It can be noticed that the most significant peak value of the E-field is recorded around 100 Hz.

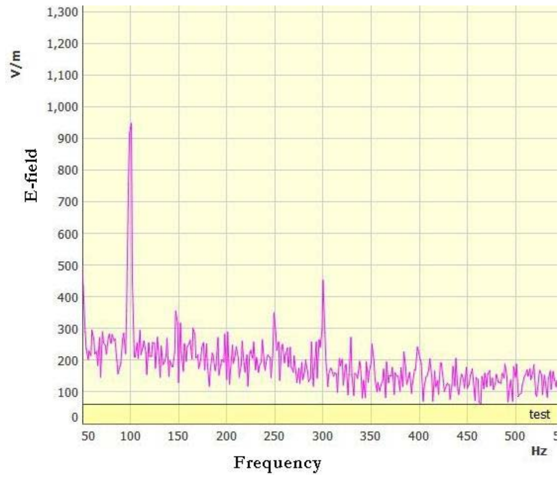

Fig.5 NTP discharge E-field at 20 cm – Aaronia Spectran NF analyzer

For the same measurement configuration, was determined the H-field variation in the considered frequency domain and graphical represented in Fig.6. The highest intensity of the H-field was obtained for the lowest frequencies.

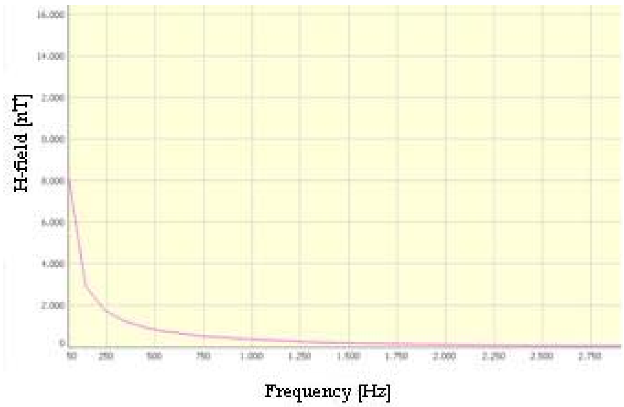

Fig.6 NTP discharge H-field at 20 cm – Aaronia Spectran NF analyzer

In order to achieve an evolution of the field propagation over distance, for the same non thermal plasma discharge were performed measurements at different distances from the discharge point. In Fig. 7 is represented the current and voltage spectrum acquired at a distance of 150 cm from the discharge occurrence. In can be observed that the voltage has a considerably decrease, so that the resulted field decreased.

Measurements of the radiated field were performed at six different distances from the plasma discharge, taking into consideration the discharge environment: only air and air water spray.

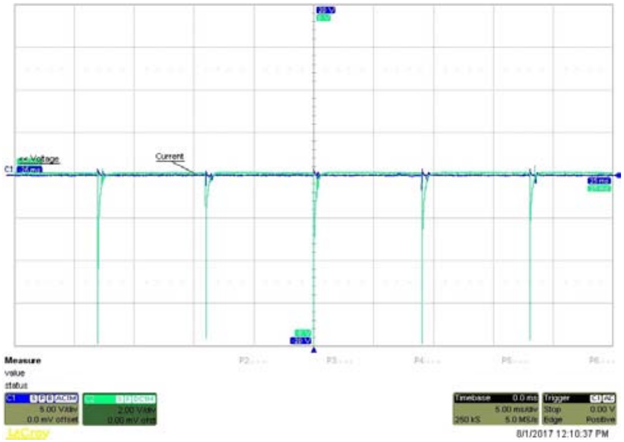

Fig.7 NTP discharge voltage and current spectrum at 150 cm – Lecroy oscilloscope

In Fig. 8 is illustrated a comparative diagram for the E- fields obtained for the above mentioned scenarios. It was concluded that the measurements performed in air water spray environment,, leaded to higher values of E-field. As the distance increases from the discharge point, the radiated field intensity substantially declines, for both discharge environments. The above graphical representation in for for 1.5 l/min air flow and 0 respectively 7ml/min water flow.

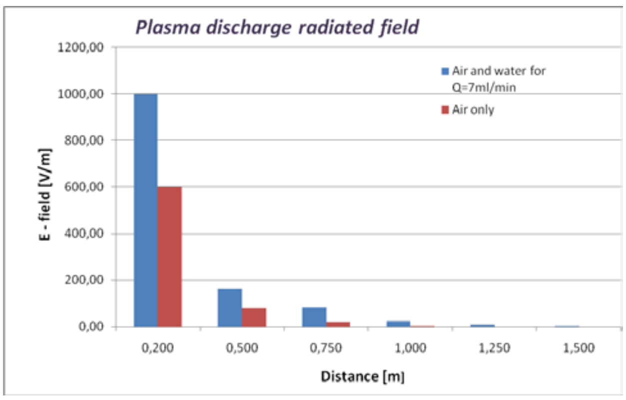

Fig.8 NTP discharge radiated E-field – distance dependence

As it was observed that the discharge environment influences the E-field intensity, it was also studied the electromagnetic stress propagation for a different water flow rates spayed in air in the discharge room. For the same measuremnt setup, there were performed voltage level measurements, for 10 ml/min water flow, for 1.5 l/min air flow. In Fig.9 is represented the voltage spectrum recorded at 75 cm from the discharge.

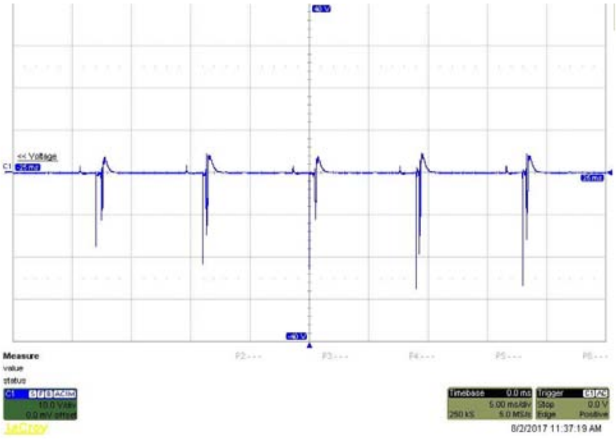

Fig.9 NTP discharge voltage spectrum at 75 cm– Lecroy oscilloscope

For the recorded E-fields in the case of 10 ml/min water flow, was represented the distance dependence of plasma discharge radiated field and graphically dispayed in Fig. 10.

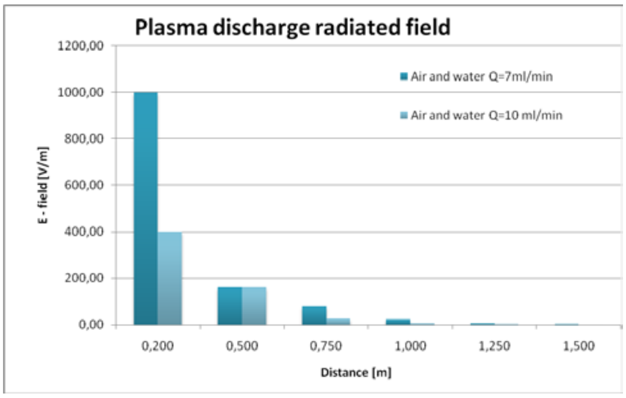

Fig.10 NTP discharge radiated E-field – distance dependence

IV. CONCLUSIONS

To obtain reactive molecular species in water films using non-thermal plasma technique in surface discharge reactors it must be considered the electrical power of the discharge, the water flow rate and the reactors configuration.

In this paper were determined the electromagnetic perturbation levels resulted from a surface discharge reactor used to produce non-thermal plasma on water film for depollution applications.

It was concluded that the discharge environment influences the radiated field strength in the surroundings of the non thermal plasma discharge. As the distance from the discharge point increases, the strength of the radiated electromagnetic stress considerably drops.

Also, it was concluded that the water flow has a significant influence on the electromagnetic field values.

ACKNOWLEDGEMENT

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