Study of the Energy Characteristics and the Temperature Influence on the Liquid Medium Resistance during the Formation of a High Voltage Discharge

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Abstract –**Under the formation of high voltage discharges in a liquid medium many physical and chemical processes occur, which depend on many different factors (characteristic of the electric field, composition of the liquid medium, external parameters such as temperature, pressure, etc.). Considering the dynamics of these processes, the purpose of the present work is experimental study and analysis of the influence of the temperature and the energy characteristics on the liquid medium resistance change at the formation of a high-voltage discharge pulse. The obtained results and dependencies can be used for design of devices for formation of such discharges in liquids for different technological applications.**

Keywords – ***High voltage discharge in liquid, Capacitive energy accumulation, Periodically attenuating discharge pulse.***

I. Introduction

High voltage pulse discharges in liquids are an object of many scientific researches. The specifics of the processes which occur in the liquid medium are related to the appearance of shock waves, UV radiation, generation of chemically active components, ozone and others. Such electrical discharges are widely used for water treatment aiming biological disinfection, cleaning of scaling and deposits on pipes, removal of chemicals in liquids, etc. [1,3]

The resistance of the formed plasma channel at a high voltage discharge in liquid depends on the alteration of the free current carriers concentration in it. Some of the factors which impact on the process are:

- recombination of current carriers;
- drift movement of current carriers;
- scattering of current carriers outside the plasma channel at the expense of a thermal diffusion and appearance of a hydraulic wave.

The processes develop with high dynamics and different time constants, which most commonly depend on the structure of the medium, external factors (temperature, parameters of the electric field, elements of the discharge circuit and spatial geometry of plasma channel [6]. Their mutual influence is difficult to be covered analytically and this requires conducting of parametric experimental studies. The results from them can be used for the design of devices for formation of high voltage discharge pulses in liquids for certain technological applications.

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The present work is dedicated on the experimental study and analysis of the influence of the liquid medium temperature and the energy parameters of the formed discharge pulse on the liquid resistance alteration.

In Section 2, the experimental system and the obtained results from the conducted experiments are presented. The analyses are presented in Section 3. The concluding remarks are given in Section 4.

II. Experiment

A. Prototype

The experiments are conducted by using the prototype system, showed in Fig.1 [2].

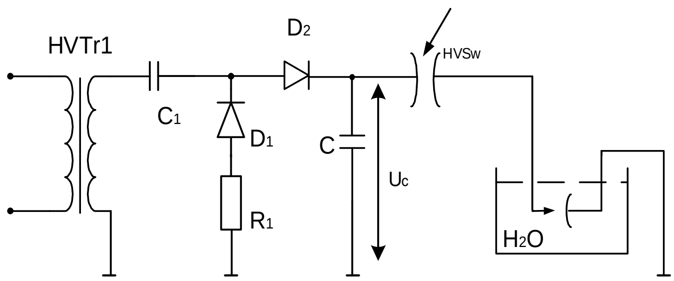


Fig.1 Device for formation of high voltage discharges in water

The charging circuit consists of a high voltage transformer (HVTr1) and a voltage doubler (C_1, D_1, D_2, C), which charges the work capacitor battery C. The discharging circuit includes a high voltage switch (HVSw) – trigatron – Fig.2 and the discharge gap in the water.

The trigatron is a three – electrode air discharger with two separated discharge circuits and two spatially divided gas-discharge channels, which evolve consistently in time. The first channel ensures the appearance of a discharge between the control electrode and the hemispherical electrode adjacent to it. The other channel forms a high voltage pulse discharge on the base of the energy accumulated in the capacitor battery between the two hemispherical electrodes. The commutation capabilities of the trigatron has been investigated in the literature [2].

Determining the alteration of the liquid resistance is important with respect to the sizing of the charging and discharging circuits.

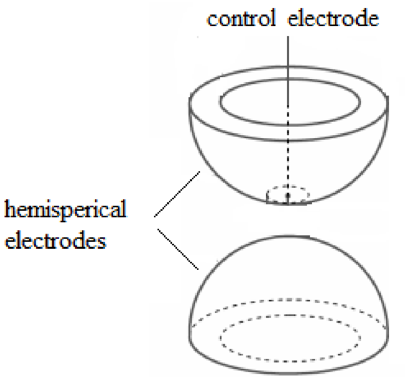


Fig.2 Trigatron

The experimental study of a high voltage discharge pulse in water is conducted with the following parameters of the system from Fig.1:

- Capacitance of the work capacitor battery C=1÷3μF;
- Voltage, to which it is charged – U_c=8,5÷12kV;
- Temperature of the water – T=16÷90°C.

B. Experimental results

The energy characteristics of the discharge pulse have been recorded for all values of the described parameters above.

The formed high voltage discharge pulse has a periodically attenuating character. The time diagrams of the discharge current and discharge voltage for some values of the parameters are shown in Fig.3 ÷ Fig.5. On the graphs – the upper curve presents the discharge voltage and the lower one – the discharge current.

The discharge current can be described by Eq.1 [5]:

$$\frac{d^2 i}{dt^2} + 2\delta\frac{di}{dt} + \omega_0^2 t = 0 \qquad (1)$$

where:

- i (t_0) = 0 – initial condition;
- $\delta = \frac{R}{2L}$ is damping ratio;
- $\omega_0^2 = \frac{1}{LC}$ - resonant frequency of the circuit.

When δ<<ω, the process is periodically attenuating.

For the circuit resistance R is valid R = $R_{HVSw} + R_L$, where the R_{HVSw} is the resistance of the trigatron and R_L is the resistance of the liquid medium.

Two consecutive periods from the discharge formation can be observed on the time diagrams:

- Predischarge period – the time between the moment of arising a discharge in the trigatron, followed by accumulation of current carriers in the discharge gap and appearance of the discharge in the liquid medium;
- Discharge period (duration of the high voltage discharge pulses) – from the moment of the discharge appearance in the liquid medium until the attenuation of the discharge process.

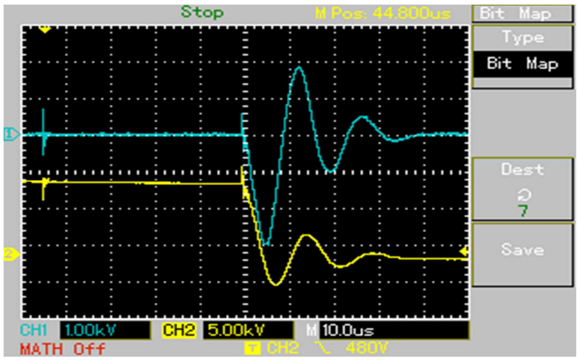


Fig.3 Discharge current and discharge voltage at C=1μF, T=16ºC, Uc=11kV

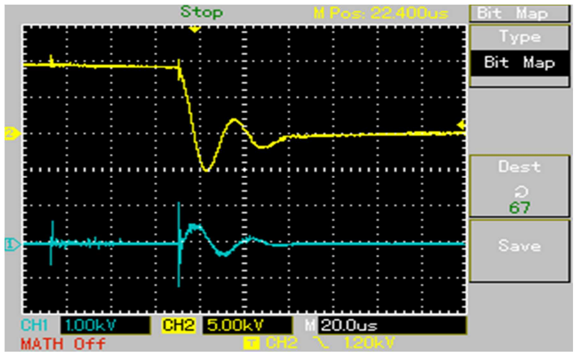


Fig.4 Discharge current and discharge voltage at C=3μF, T=60ºC, Uc=11kV

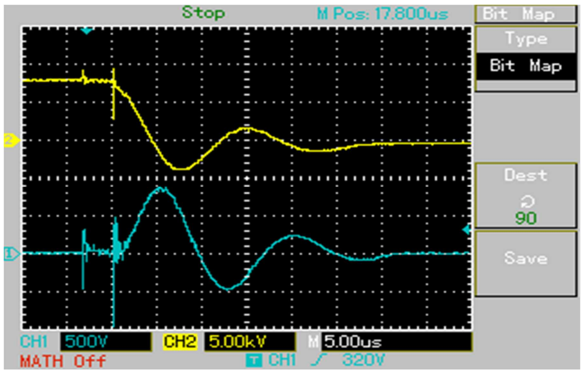


Fig.5 Discharge current and discharge voltage at C=1μF, T=90ºC, Uc=9,5kV

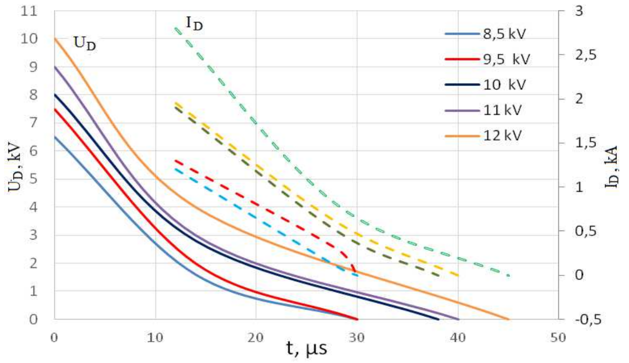
From the conducted experiments it can be noticed that the change of the predischarge period has a random character and does not depend on the change of the liquid medium temperature. This fact is due to the different parameters of the liquid medium before the appearance of each separate discharge pulse, which depend on different factors. The predischarge time does not depend on the capacitance of the capacitor battery and the voltage U_c [4].

III. Analysis

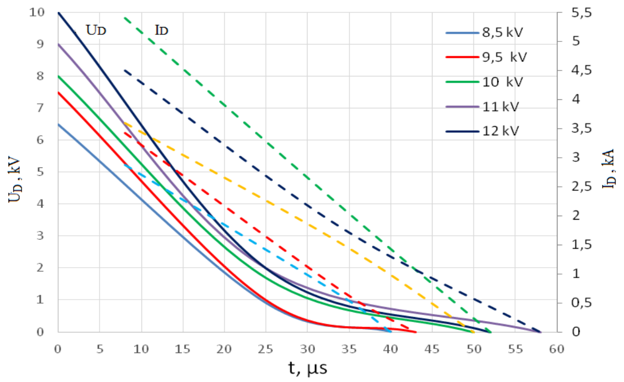
The experimental results have been analyzed by using the following methodology:

- Defining the discharge process duration;
- Recording the values of the discharge current and discharge voltage for all maximums of the positive half-wave and the moment of their appearance from the high voltage periodically attenuating oscillations;
- Drawing the wrap curves from the amplitude values of the discharge current and voltage;
- Calculation of the liquid medium resistance R_L on the basis of the obtained curves.

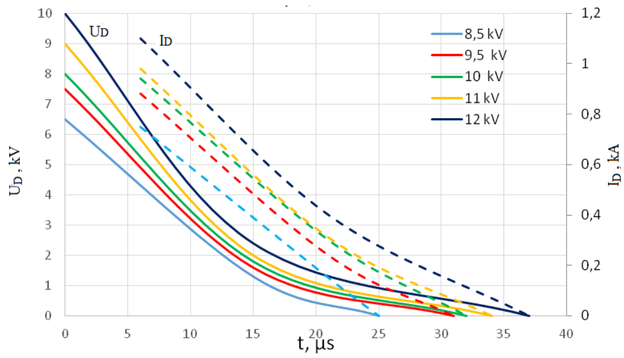
In Fig.6 are presented the wrap curves of the discharge current and discharge voltage for some values of the parameters C, U_c and temperature of the liquid medium.



a) C=1µF and T=16ºC



b) C=3µF and T=60ºC.



c) C=1µF and T=90ºC.

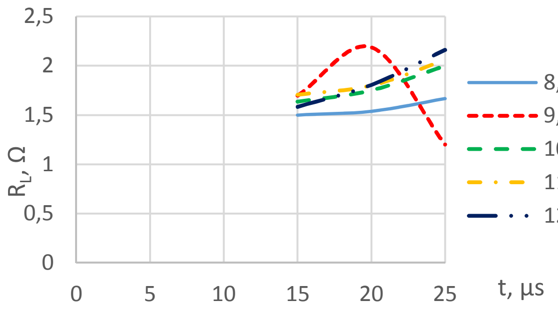
Fig.6 Wrap curves of the amplitude values of the discharge current and voltage

When increasing the capacitance of the work capacitor battery and the voltage, to which it is charged, the values of the discharge current and discharge voltage increase, too. That is due to the higher energy, accumulated in the capacitor battery.

The discharge process duration shortens with increasing the temperature and decreasing of C, because of the higher electrical conductivity of the liquid medium.

The alteration of liquid resistance at the arising of a high voltage periodically attenuating discharge pulse is defined on the basis of the wrap curves – Fig.7. For comparison, the results are presented for the same values of C, Uc and the temperature T as in Fig.6 a,b,c.

The values of the resistance vary within the range 0,39÷10,5Ω.



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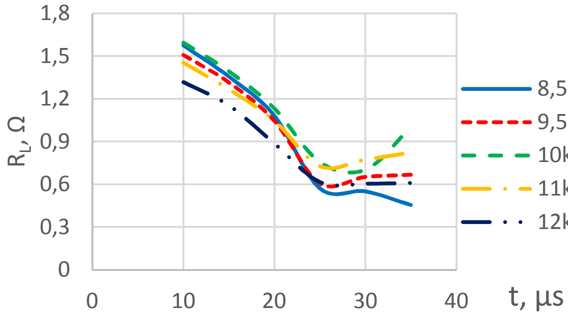
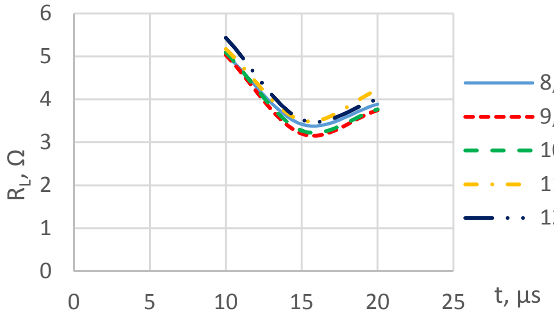


b) C=3µF and T=60ºC.



c) C=1µF and T=90ºC.

Fig.7 Resistance of the liquid medium during the discharge process

At higher capacitance of the work capacitor battery it is observed decreasing the resistance and changing of the curve character – Fig.8.

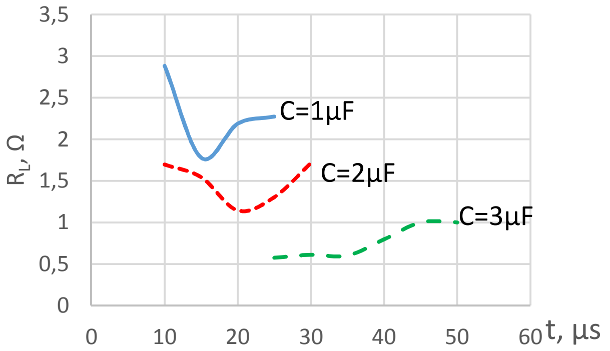


Fig.8 Resistance of the liquid medium at T=34ºC and Uc=10kV

For a certain type of the characteristic of the resistance alteration at arising of the high voltage periodically attenuating discharge pulse a model for analysis by approximation with a suitable mathematical function is proposed [5].

During high voltage periodically attenuating discharge in liquid, the main part of the energy is released in the first half-wave of the process. The resistance alteration depending on the temperature during this period for Uc=9,5kV is presented in Fig.9.

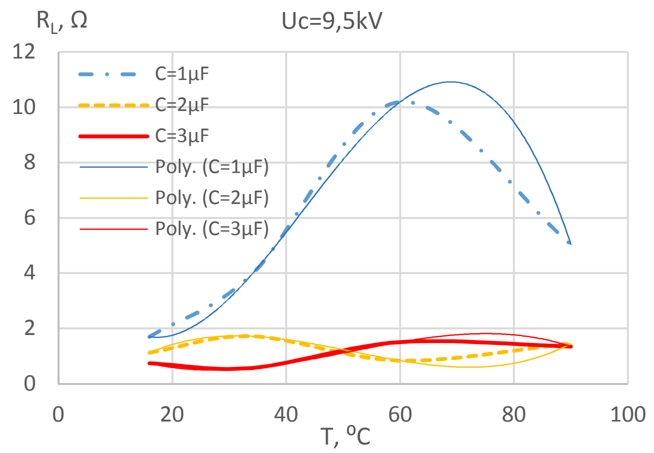


Fig.9 Resistance of the liquid medium for the first half-period of the discharge process

The same curves are observed and for the other values of the voltage U_c.

The curves from Fig.9 could be approximated with sufficient accuracy with third order polynomials (shown with thinner lines next to each of the experimental curves). The respective equations are:

- for C=1μF

$$y = -1,34*10^{-4}x^{3} + 0,017314x^{2} – 0,477706x + 5,456026 \quad (2)$$

- for C=2μF

$$y = 34*10^{-6}x^{3} - 0,005214x^{2} + 0,227871x - 1,323895 \quad (3)$$

- for C=3μF

$$y = -24*10^{-6}x^{3} + 0,003660x^{2} - 0,145547x + 2,228896 \quad (4)$$

The relationship between the polynomials coefficients and the values of C and U_c should be subjected to future analysis.

The approximation with a mathematical function gives a possibility for preliminary assessment of the liquid medium resistance. This is necessary for the design of devices for control of high voltage discharge pulses in liquids and for sizing of the charging and discharging circuits.

IV. Conclusion

A high voltage pulse discharge in liquid (water) has been experimentally studied as:

- the energy characteristics of the periodically attenuating discharge process (discharge current and voltage) are taken down at parameters: capacitance of the work capacitor battery; voltage, to which it is charged to and the temperature of the liquid medium;
- the liquid resistance alteration for different temperatures of the water during the discharge process is defined.
- it is proposed a description of the liquid resistance alteration with a mathematical function - third order polynomial.

The received results and dependencies can be used for sizing of systems for generation of high voltage discharge pulses for different technological applications.

Acknowledgement

The presented results in the current paper are obtained under working on project Д002-18/23.02.2009, financed by the Scientific Research Fund at the Ministry of Education and Science of Republic of Bulgaria.

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