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Research of generators of impulses for electrotechnological installations with solutions of electrolytes

Article is devoted to functioning of pulse electrotechnological installations on low frequency (0,1 Hz) and industry frequency. As an analog schemes of pulse relaxation generators for processes of electric erosion machining of metals are considered. Also RC-generators and static generators of impulses (transformers of the industry frequency with the gate) were considered. Pulse RC-generators on voltage of 1000 V and a pulse repetition rate of 0,1 Hz and the static generator of impulses on voltage of 1000 V and a pulse repetition rate of 50 Hz are developed. Experiments on studying of development of the partial (sliding) electric discharge with attenuation at the 1st stage and with transition to the second stage are made. Experiments on studying of a complete and incomplete electrical breakdown of electrolytes are also made. An analogy was found between the course of the discharge in the electrolyte and the surface of a solid dielectric covered with a thin film of electrolyte. In both cases, discharges first develop in the form of a pre-discharge current of small magnitude, and end with a transition to a high-current discharge (breakdown). It is shown that the measured delay time of electric discharge (4 microsec) much less a delay time of the electrothermal category (30 microsec). Owing to this fact breakdown in this case has to be it is carried rather to electric, than to a thermal look.

Keywords: electrotechnological installations, generators of impulses, pulse relaxation generators, static generators of impulses, discharge in electrolyte, partial creeping discharge on solid dielectric, test.

Introduction

Studies of electric discharge technologies of low voltage were widely carried out in the seventies years of the last century at Institute of mining name of D.A. Kunayev. They led to development of new pulse devices, for example, of pulse current generators [1]. Advantage of low-voltage devices consists in their low cost and reliability. Instead of dear operated dischargers, pulse high-voltage capacitors, there was an opportunity in some electrodischarge processes to apply magnetic contactors and low-voltage capacitors.

Now electrotechnological installations are widely used in the industry. They include a wide range of installations for electroerosive machining of metals, electrochemical machining, electrohydraulic machining, installations for plasma processing of materials, electric filters, etc. [2]. At the same time there are new electronic and ion technologies, which in something are similar, and in something differ from the predecessors. When putting into operation new electrotechnological installations a logical step is use of already existing electric equipment taking into account new specifics.

When developing the electronic and ion technologies including the discharge in electrolyte at low voltage and the partial discharge of low voltage in the presence of electrolyte. Therefore the purpose of this work was development and a research of pulse power supplies for new processes.

From all set of the electrotechnological processes described in monography [2] we selected technology and the equipment for electric erosion machining of metals. It was made owing to strong likeness of processes of electric erosion machining with processes of impulsing breakdown of electrolytes and the impulsing partial discharge. The schematic diagram of the power supply of pulse installations on the basis of the relaxational RC-generator described in works [3, 4] is submitted in Figure 1.

As the discharger for creation of conditions of existence of the partial discharge the automobile spark plug processed 1,5 % by NaCl solution was used.

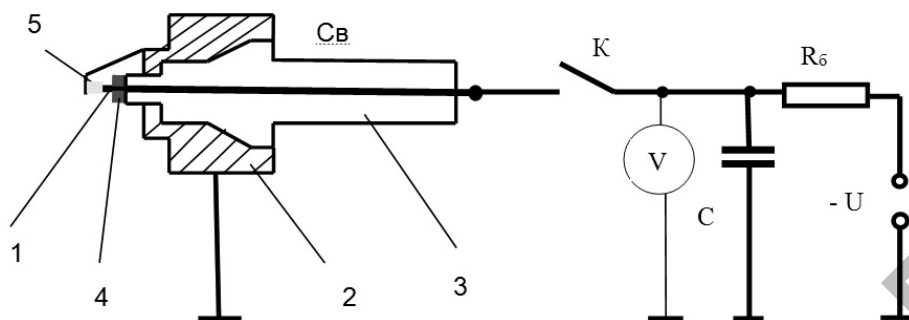
Time of a charge of the capacitor C up to 99,2 % in our case is defined as

$$\tau = 5R_0 \cdot C = 5 \cdot 10^5 \text{ Ohm} \cdot 20 \cdot 10^{-6} \text{ F} = 10 \text{ s.}$$

It gives the chance to pulse with a frequency of 10^{-1} Hz.

At short circuit of the switch K on the discharger voltage impulse with an amplitude of 600 - 800 V is formed. In a pulsed operation the capacitor was charged at the opened switch K. Then the switch K became isolated and voltage impulse entering on the discharger's electrodes was formed. In this case ignition of the

partial discharge happened during voltage pulse length (about 30 microseconds lasting front of 2 microseconds). The similar source allowed to make experiments on dynamics of development of the partial discharge (Fig. 2).



U – a source of constant voltage of 0 - 1000 V; $R_b = 10^5$ Ohms – a ballast; $C = 2 \cdot 10^{-6}$ F – capacitor; V – the digital voltmeter; K – switch; C_B – the spark plug; 1 – an electrode; 2 – the grounding electrode; 3 – a dielectric; 4 – place of ignition of the first stage of the partial discharge; 5 – a discharge gap (the place of ignition of the second stage of the partial discharge)

Figure 1. Scheme of the pulse relaxational generator

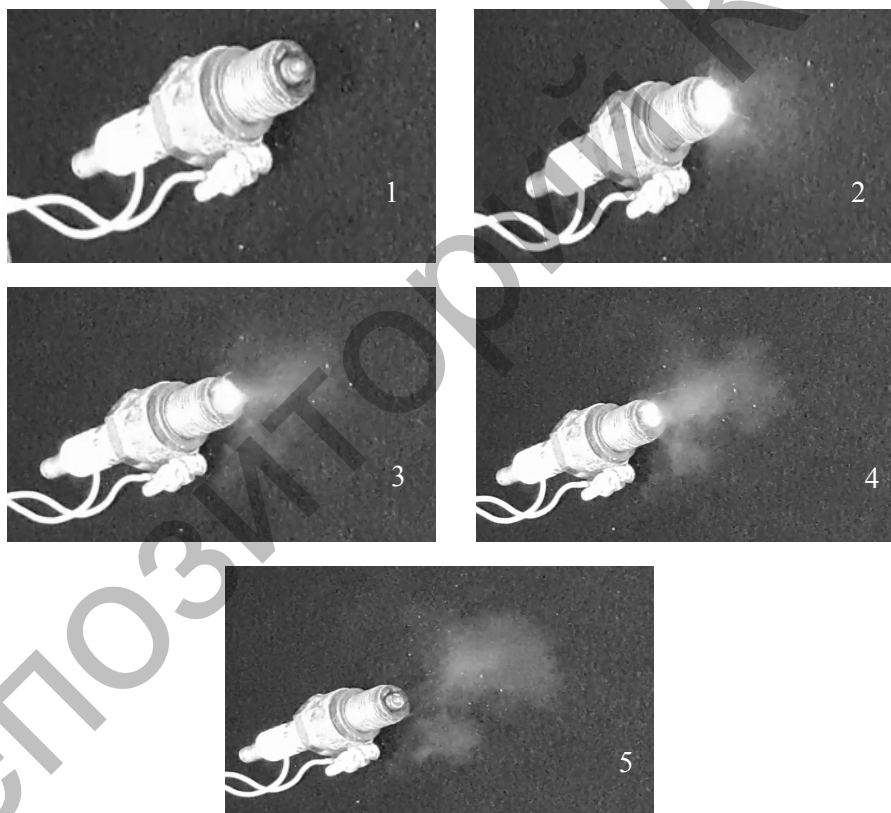
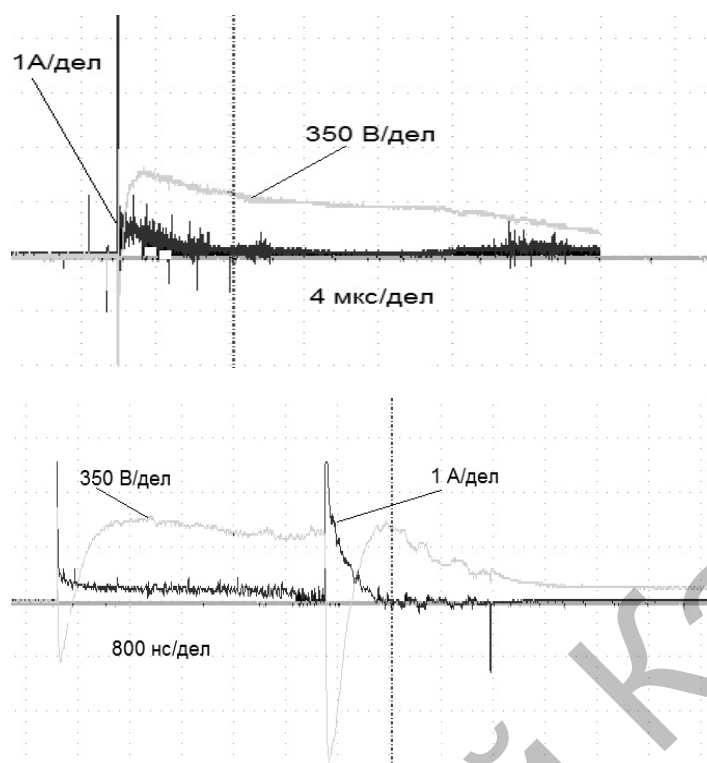


Figure 2. Dynamics of development of the first stage of the partial discharge at power supply from pulse relaxation RC-generator: $U = 610$ V, $\Delta t = 1/30$ s

In Figure 2 the moment of ignition of the partial discharge is well visible (a photo 2). During 0,1s it exists while the capacitor on an automobile spark plug is discharged (a Photo 2–4). On a photo 5 the moment of extinction of the partial discharge is visible. Reddish color of radiation of the partial discharge testifies to the low temperature of plasma in the period of the first stage of the discharge.



a) the discharge gap did not break through; b) the discharge gap broke through

Figure 3. Oscillograms of current and voltage when giving an impulse on a discharge gap (spark plug) through resistance $R_1 = 1 \text{ Ohm}$

In Figure 3 oscillograms of current and voltage at electrolyte breakdown by the spark discharge at a power supply from the RC generator of impulses are submitted. In Figure 3a breakdown does not happen though processes before breakdown develop. It is visible that through a discharge gap current about 15 A begins to flow. Then for 4 microsec it decreases to 10 A and all the time of existence of voltage impulse flowed. However breakdown at the same time does not happen. It is bound, according to us, to the fact that for 20 microsec voltage impuls already decreased from 750 V to the level of 300 V.

In Figure 3b initial current significantly higher than 30 A with decrease to 20 A. Therefore processes before breakdown develop during the entire period of 4 microsec. At the same time voltage on a discharge gap during this time decreases from 750 V to 700 V. This voltage is quite enough for breakdown of a discharge gap. At the same time current increases to 270 A. Voltage on a discharge gap sharply falls. The discharge current decreases to zero. There are processes of a deionization. Voltage on a discharge gap begins to increase because the capacitor C did not manage to be discharged completely. After that the condenser is discharged through resistance of oddments of electrolyte, but one more breakdown at a sufficient capacitor capacitance is possible [4].

Static generator of impulses

The static generator of impulses represents the symmetric rectifier with quadrupling of voltage. The symmetric scheme represented in Figure 4 [5] represents a combination of two schemes of the half-wave rectifiers with a doubled of voltage, working in different half-cycles of voltage of a power line. Work of this scheme happens as follows. During a half-cycle of one sign C_1 and C_4 capacitors are charged, and voltage on the C_1 capacitor reaches, approximately, unary, and on the C_4 capacitor — the doubled effective value of voltage of a power line (the C_4 capacitor is charged, using already available charge on the C_2 capacitor). During a half-cycle of the counter sign C_2 and C_3 capacitors are in the same way charged. Rectified voltage is removed from the corresponding poles of the C_3 and C_4 capacitors connected between themselves is serial. Thus, it doubles for the second time.

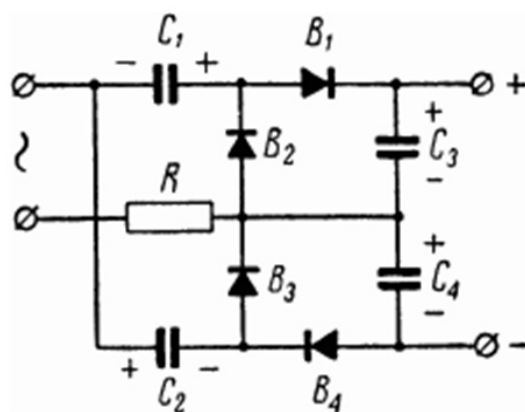


Figure 4. The static generator of impulses on the basis of the symmetric scheme of the rectifier with quadrupling of voltage: $R=135$ Ohms, C_1-C_4 of MBGO 500 V, $20 \mu\text{F}$, $U \sim = 220$ V, $- U_{\text{xx}} = 1242$ V

Voltage up to which C_1 and C_2 capacitors are charged is that larger, than more load resistance or, in other words, less power given by the rectifier. Charge voltage reaches the maximal value in case of disconnection electrical load from the rectifier. In this case it becomes equal to amplitude value of voltage of electric grid (is 1,41 times more larger than an effective value) on C_1 and C_2 capacitors and to the doubled amplitude value (is 2,82 times more larger than an effective value) — on C_3 and C_4 capacitors. At alternating-current nominal voltage of $U_n = 220$ V the maximal voltage of a rectified current was 1242 V. Time of a charge of C_3 and C_4 capacitors is defined as

$$\tau = 5R \cdot C = 5 \cdot 1,35 \cdot 10^2 \text{ Ohm} \cdot 20 \cdot 10^{-6} \text{ F} = 13,5 \cdot 10^{-3} \text{ s.}$$

At the same time the voltage value is enough for transition of the discharge to the second high-current stage. The discharge lights up (a Photo 1) and in 1/30 sec. passes into the high-current stage characterized by bright flash and a loud sound (a Photo 2). After the discharge of the capacitor and a deionization of a discharge gap there is an increase in voltage and charging of capacitors owing to what primary stage of the partial discharge (a Photo 3) which passes into the second stage etc is again lit.

Comparing Figures 2,3,5 it is possible to note a number of circumstances:

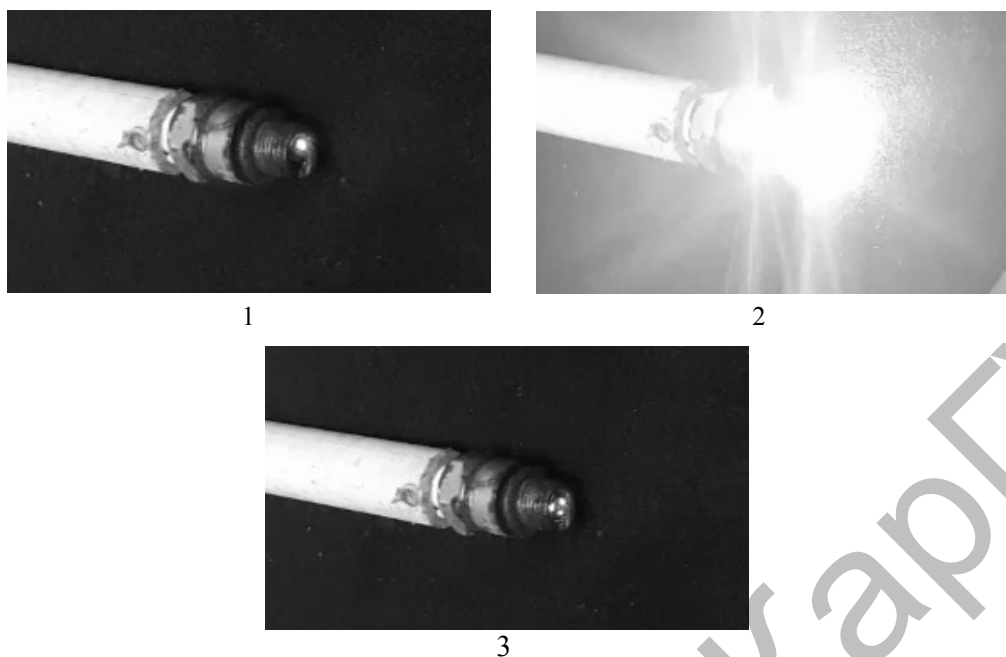
a) *Figures 2 and 3a*. It is possible to speak about similarity of creeping discharge on solid dielectric (1 stage) which does not pass into the second stage (breakdown), with predischarge current in electrolyte which does not pass into the discharge (breakdown).

b) *Figure 5 with Figure 3b*. This similarity of a creeping discharge of a dielectric (the first stage with transition to the second stage - breakdown) with predischarge current in electrolyte which turns into electrolyte breakdown. Though predischarge current also decreases, nevertheless there is a breakdown.

The similarity of the partial discharge to the discharge in electrolyte is that the charged particles with particular concentration are formed at the expense of the molecules H_2O and NaCl dissociated on ions. At the discharge in distilled water the charged particles are formed due to ionization of molecules by ions in an electric field of high strength.

The delay time of the discharge of 4 microsec is much lower than a delay time of the electrothermal discharge (30 microsec according to work [4]). For this reason breakdown in this case has to be referred rather to electric, but not to a thermal type of breakdown. That is gas emission at course of current and a heat liberation in a discharge gap does not happen.

If as loading the automobile suppository was used, then voltage fluctuated from 400 V to 800 V. In Figure 5 photos of the partial discharge at a power supply from the static generator of impulses are shown.



A photo 1, 3 – the partial discharge the first stage, a photo 2 – the partial discharge the second stage

Figure 5. Dynamics of development of the partial discharge with its transition from the first to the second stage at a power supply from the static generator of impulses on the basis of the symmetric rectification scheme with quadrupling of voltage. $U = 1242$ В, $\Delta t = 1/30$ s

Conclusion

1. The pulse generator with a frequency of 0,1 Hz is developed for power supply of pulse installations on the basis of breakdown of electrolytes and the partial discharge on a surface of a solid dielectric in the presence of electrolyte. It is an analog of the pulse relaxation RC generator for electroerosivemascining of metals. For creation of the generator low-voltage magnetic contactors of KMI - 10910 and low-voltage capacitors MBGP-1 10 μ F, 1500V are used. Impulses of voltage lasting front of 2 microsec and a pulse length of 30 microsec are received.

2. The static generator of impulses on the basis of the symmetric scheme of the rectifier with quadrupling of voltage and mains supply of 220 V alternating-current is developed for generation of potent electric impulses of the industry frequency. At the exit voltage of 1242 V of a direct current in the mode of a no-load operation is received. In the mode of the partial discharge voltage is from 400 to 800 V.

3. Experiments on work of pulse generators in the modes of the partial discharge with attenuation in the first stage and with transition to the second stage (a breakdown stage) are made. During the experiments on breakdown of electrolyte the delay time of 4 microsec, too small for electrothermal breakdown is registered.

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Электродиттер ерітіндісі бар электртехнологиялық құрылғылар үшін импульсті генераторларды зерттеу

Мақала төменгі (0,1 Гц) және өндірістік жиіліктегі импульсті электртехнологиялық қондырғылардың жұмысына арналған. Аналог ретінде металдарды электррозиямен өңдеу процесі үшін импульсті релакциялық генераторлар, RC-генераторлар және импульстардың статикалық генераторларының (вентилі бар өнеркәсіптік жиілікті трансформаторлар) сұлбалары қарастырылды. Кернеуі 1000 В, импульстардың қайталану жиілігі 0,1 Гц, импульстік RC-генераторлары және кернеуі 1000 В, импульстардың қайталану жиілігі 50 Гц болатын статикалық генератор әзірленді. Бірінші сатыда өшіп және екінші кезеңге өтетін бөлшектік (сырғитын) разрядтың дамуын бақылау тәжірибесі жүргізілді. Электродиттердің аяқталған және аяқталмаған бөліктерін зерттеу үшін тәжірибелер өткізілді. Разрядтың электродитте және электродиттің жұқа қабықшасымен қапталған қатты диэлектрик бетімен ағуы арасындағы аналогия анықталды. Екі жағдайда разрядтар (сынақ) бастапқыда аз көлемді ток түріне арналған кейіпте, кейін анық айқын разрядқа өтумен аяқталады. Разряд кешігуі айтарлықтай аз, 4 мкс, ал электржылулық разряд кешігуінен 30 мкс. Онда бұл жағдайда бұзылу көп жағдайда жылулық түрден гөрі электрлікке жатқызылуы керек.

Кілт сөздер: электртехнологиялық қондырғылар, импульстер генераторы, импульстік релаксациялық генераторлар, импульстардың статикалық генераторы, электродит разряды, қатты диэлектрик бетімен бөлшектік разряд, сынау.

Е.А. Яковлев, А.Д. Мехтиев, В.В. Югай, Л.А. Зиновьев

Исследование генераторов импульсов для электротехнологических установок с растворами электролитов

Статья посвящена работе импульсных электротехнологических установок при низкой частоте (0,1 Гц) и промышленной частоте. В качестве аналога рассматриваются схемы импульсных релаксационных генераторов для процессов электроэрозионной обработки металлов — RC-генераторы и статические генераторы импульсов (трансформаторы промышленной частоты с вентилем). Разработаны импульсные RC-генераторы на напряжение 1000 В и частоту следования импульсов 0,1 Гц и статический генератор импульсов на напряжение 1000 В и частоту следования импульсов 50 Гц. Проведены опыты по изучению развития частичного (скользящего) разряда с затуханием на 1-й стадии и с переходом во вторую стадию. Проведены опыты по изучению заверщенного и незавершенного пробоя электролитов. Выявлена аналогия между протеканиями разряда в электролите и по поверхности твердого диэлектрика, покрытого тонкой пленкой электролита. В обоих случаях разряды развиваются сначала в виде предразрядного тока малой величины, а заканчиваются переходом в сильноточный разряд (пробой). Установлено, что время запаздывания разряда 4 мкс гораздо меньше времени запаздывания электротеплового разряда 30 мкс. Тогда пробой в данном случае должен быть отнесен скорее к электрическому, нежели к тепловому виду.

Ключевые слова: электротехнологические установки, генераторы импульсов, импульсные релаксационные генераторы, статические генераторы импульсов, разряд в электролите, частичный разряд по поверхности твердого диэлектрика, испытания.

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