

Usage of high voltage impulse generator to research the process of electropulse destruction of locust larvae in the soil

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Abstract. In accordance with announced technology, a laboratory research complex is needed for researching the influence of electropulse effects on locust larvae (capsules) and identification of the processing modes and construction design required to cause their irreversible (fatal) damage. In this regard, a schematic diagram of a laboratory research complex for electropulse processing has been developed and its structure has been determined. A separate question concerned a source of high voltage and a shaper of high-voltage impulses. A special design of a high-voltage impulse generator has been developed. This design can produce impact impulses of various durations - the impulse duration depends on the capacitive storage; with maximum amplitude of 16 kV and current per impulse of up to 400 A. The generator uses a capacitive storage discharge through a thyatron controlled by a microcontroller to the load. The proposed high-voltage impulse generator is necessary for researching the effect of electropulse high-voltage technology on the irreversible damage of locust larvae located in the soil layer, and for the experimental identification of the operating modes of the electrical part of the designed electrotechnological system, which allows for destruction of locust capsules directly in the field. The designed high-voltage generator was tested in operational mode when working with a load, which was the soil volume placed between the electrodes in the working chamber. The shape of the operational impulse and its parameters comply with predefined characteristics for electropulse cultivation of soil massif with locust larvae (capsules). After the tests, minor structural adjustments were made, and the generator itself was prepared for experimental studies in the laboratory.

1. Introduction

At the moment, various electrical technologies and equipment kits based on these technologies are effectively and actively used for growing agricultural products and processing them at factories. Of all the types of electrophysical effects on objects of plant origin, electro impulse supply of electrical energy to the plants is considered not only safe from the point of view of food and environmental aspects, technologically effective, but also an energy-saving measure. [1-5].



Some electro impulse technologies are aimed at delivery of fatal outcomes, i.e. elimination of flying insects or creation of irreversible damage to intracellular structures of plants to combat unwanted and weedy vegetation, pre-harvest treatment of sunflower and tobacco plants, etc. [6-8].

Electric effect of lethal doses has been used in combating blights, harmful insect and diseases living in the soil under crops since the 18th century. But at the moment these studies are still ongoing, which allows us to obtain new information about the mechanisms of irreversible damage to biological tissue of insects, to develop new technical means and improve the applied electrical technologies, to reduce the cost of energy used with no damage to the environment. "Electric projectile for the mass elimination of insects harmful to agriculture" is considered to be one of the first systems used for electrical destruction of insects and their slugs living in the surface soil layer. This system was constructed by Russian electrical engineer Z. Lokutsevsky and was described in 1903.

Scientists of the All-Union Research Institute of Forestry (A.V. Lugovoi, S.Ya. Turlygin, D.S. Beklemyshev) were engaged in a search of a more detailed solution to this problem using experimental justification and verification, both in laboratory and in the field since 1936 to 1939. This group of researchers found out that it is most effective to use the "impulse form of energy application" characterized by the following parameters: amplitude of the voltage pulse - 4.0–9.0 kV; gradient of the electric field - 0.3-2.5 kV / cm; the number of impact pulses - 1-10 pcs.; discharge time constant - $1.0 \cdot 10^{-2}$ sec; the capacity of the discharge circuit up to $12.0 \cdot 10^{-6}$ F in dealing with such insects as the slug of the May beetle.[9-10].

In 1954-1956 employees of the Institute of Biological Physics of the USSR Academy of Sciences (A.A. Peredelsky, L.S. Osipova, V.N. Efimov) studied the use of high-voltage pulses for combating beet weevil and experimentally revealed the following effective modes of its fatal injury: electric field gradient – 1.0-3.5 kV / cm; the number of impact pulses - 1-12 pcs.; discharge time constant - $(0.2-1.0) \cdot 10^{-3}$ sec; discharge circuit capacity - $(0.13-1.39) \cdot 10^{-6}$ F; the density of the damaging electricity flow is 0.3-0.68 A / cm² [11].

In 1956-1958 employees of the All-Union Research Institute of Electrification of Agriculture (M.G. Evreinov, I.S. Smirnova, L.S. Lurie, A.A. Tilvikas) designed a mobile generator that allows to process the soil to fight harmful insects and worked in the following modes: pulse repetition rate - 7-30 pulses per second; electric field gradient - 1.4-2.15 kV / cm; discharge time constant - $(0.01-0.14) \cdot 10^{-3}$ sec; the capacity of the discharge circuit is $(0.32-1.54) \cdot 10^{-6}$ F [12].

In the 1970s at the Timiryazev Agricultural Academy V.T. Sklyar studied the impact of high-voltage impulse effects on bread ground beetles, chinch and slugs of the net naked, which resulted in the revelation of modes of their electric irreversible damage. Thus the energy intensity of a lethal impulse per one studied object was the following: for bread ground beetles - 1.4 J; for slugs - 1.2 J; for chinch - 1.1 J. For the destruction of the gallicascarid and the boletus-pathogen of anbury, the specific consumption of electric energy was 24.7 and 27.8 kWh / m³, respectively [13].

A separate question relates to the effect of high-voltage impulses on soil biota. Studies [14, 15] showed that, depending on the parameters of the discharge and the type of microorganisms, the effect of the discharge on the soil can lead to both inhibition and stimulation of their development. An essential parameter in this case is soil moisture. Soil with a moisture content of 10-12% during electric treatment shows that vital activity of microorganisms is stimulated and aftereffect is apparent. And soil with 18% moisture content shows the time-delayed effect of depression. Electro impulse treatment leads to an increase in mobile compounds of potassium and phosphorus by 1-2 mg / kg of soil, which corresponds to an increase in grain harvest of 0.1-0.12 c / ha. The most significant change in these compounds is observed due to the aftereffect. An increase of humus in the soil is also observed and amounts to 7–9% of its initial content (2.65%). An increase in vital activity during electrical processing is observed for the most unpretentious microorganisms — oligotrophic bacteria, which leads to increase of digestible forms of nitrogen in the soil and boletus. Soil cultivation aimed to enhance vital activity of microorganisms should not be carried out under hard modes, i.e. at high processing energy density.

At the moment, there is an urgent need to find an environmentally friendly and energy efficient way to combat locusts, which is driven by the lack of effective measures and negative impact of existing methods on the environment and soil biota primarily due to pesticides.

Locusts (also known as Acrididae) are insects of the locust family, are considered as one of the most dangerous polyphagous pests. They cause harm both to cultivated crops and to any green plants that grow in the halo of their expansion. The most dangerous are locust migratory species: Moroccan locust, Italian locust, Asian locust and Siberian filly. Specialists from the Food and Agriculture Organization of the United Nations (FAO) estimated that 1 ton of locusts a day eats as much as 2.5 thousand people. Herds of locusts are able to move at a speed of 15-20 km / h and fly up to 20 hours consecutively - live locust clouds sometimes reach 10 km in width and up to 200 km in length. One locust on average lays up to 1.5 thousand eggs. The economic threshold for harmfulness is, for the Italian locust and the Moroccan locust, 2-5 larvae per 1 m², for migratory Asian locusts, 1-2 larvae per 1 m², for non-herd locusts (filly), 10-15 larvae per 1 m².

Locust is a real scourge of all agriculture, especially in the southern regions of the Russian Federation. It destroys all crops on its path. In the Republic of Kalmykia, epiphytotic outbreaks of locust breeding are observed annually on an area of over 100 thousand ha [16]. Areas inhabited by Moroccan locusts with a huge density of their expansion were discovered in the Russian Federation in recent years. In 2019 in the North Caucasus Federal District (FD) populations of gregarious locusts were recorded on 215970 ha with a density of 11.3-200 larvae / m², non-gregarious locusts on 172950 ha with a density of 6.8-75 larvae / m². In the Southern Federal District, gregarious locust larvae were recorded on 108620 ha with densities ranging from 19.3 to 2000 larvae / m², non-gregarious species larvae on 60610 ha with densities from 1.41 to 30 larvae / m². Losses to agriculture from this harmful insect are huge.

Various physical lethal effects are considered as an alternative for insects combatting, including electrical, magnetic and electromagnetic fields; microwave energy; concentrated radiation, etc. One of the most promising methods of controlling harmful insects, including locusts, should be the use of high-voltage effects of a lethal dose, both on the egg laying in the soil and in the continuous research to destroy adult locusts [17].

It is impossible to implement the process of electro pulse influence on soil insects and their larvae without specialized electro technological equipment, which helps to build up high voltage signals with required length, frequency, amplitude, shape and bring them to the objects.

To justify the processing modes, identify energy indicators and technological characteristics, it is necessary to conduct detailed studies regarding the process of electric pulse irreversible damage to larvae and soil insects, which cannot be done without usage special electrical installations, with a high-voltage pulse generator being its main element. Moreover, these devices shall have the ability to fine-tune and control the output parameters of the impact pulses. They shall also be sustainable, lean, easy to assemble and operate and safe. Therefore, to resolve abovementioned issues, it was decided to design and manufacture a pulse voltage generator with a capacitive energy storage device, which would allow to obtain pulses with a rather steep front and an exponential slice controlled by the pulse amplitude. The aim of this work is an introduction of design features attributable to electric generator of high voltage pulses and review of a structure of an experimental research complex to study the effect of electric pulses on locust larvae.

2. Materials and methods

This research was conducted at the research facilities to examine the electric pulse processing of soil's samples in laboratory environment. The research was conducted at a laboratory of "Heat power engineering and informational management systems" department of Azov -Chernomorskiy engineering institute FGBU Donskoy GAU. An electric scheme of pulse voltage generator was developed to create this research facilities. The pulse voltage generator consists of the main blocks: control, switching and a high-voltage block. The control unit incorporates a configurable ignition

pulse generator for a pulsed thyatron, which is located in the second (switch). Let us consider in more detail the diagrams (Fig. 1) of these structures and basis for their operation.

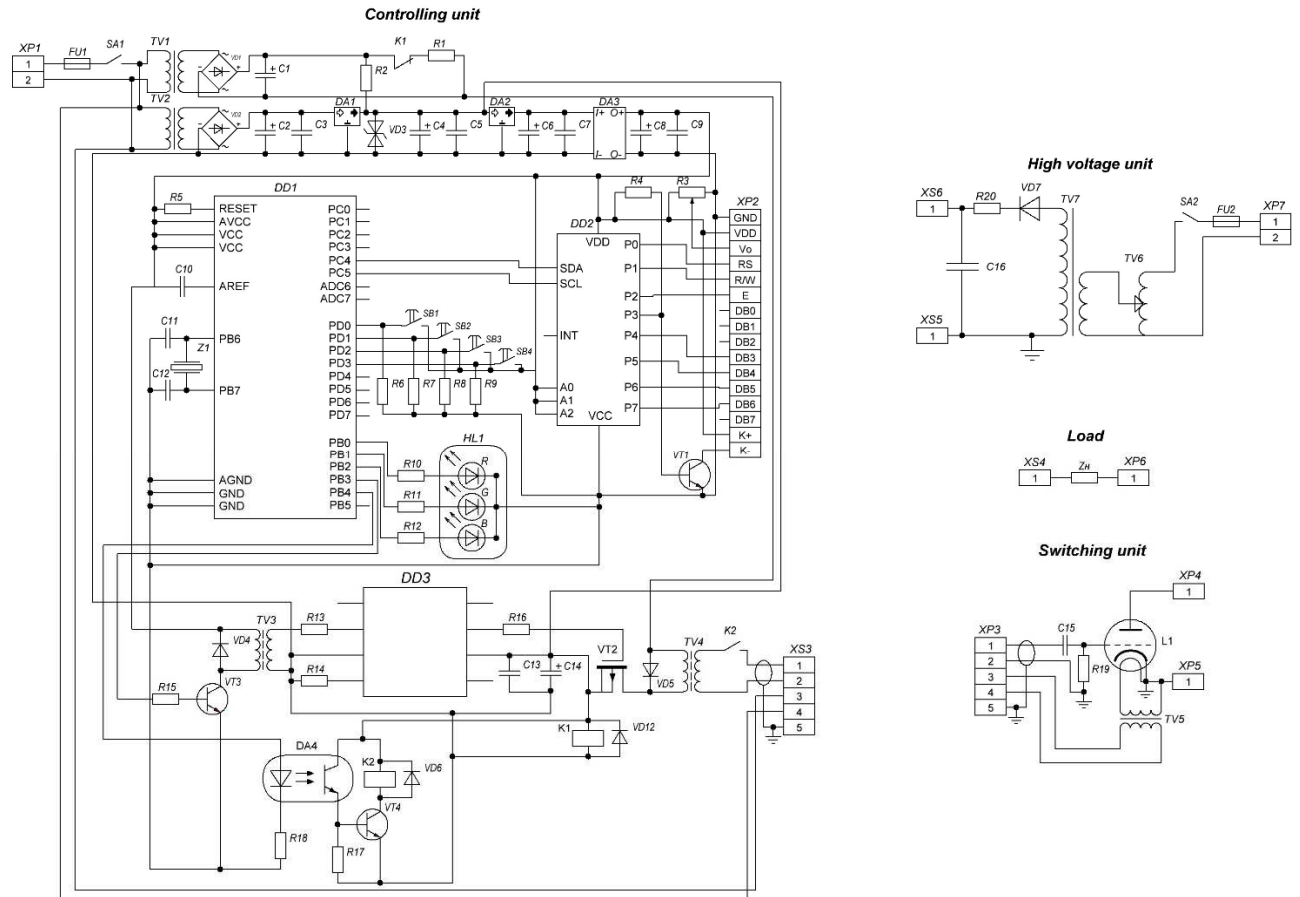


Figure 1. Schematic diagram of the impulse voltage generator (C1 - 220 μ F; C2, C4, C6, C8 - 1000 μ F; C3, C5, C7, C9 - 330 nF; C10 - 0.1 μ F; C11, C12 - 15 pF; C13 - 10 nF; C14 - 10 μ F; C15 - 2200 pF; R1, R3, R17 - 10k; R4 - 15k; R4 - 4.7k; R5, R13, R14, R15 - 1k; R6, R7, R8, R9 - 100k; R10, R11, R12, R18 - 2.7k; R16 - 10 Ω ; R19 - 5k Ω ; VD1, VD2 - BD610; VD3 - 1.5KE15A; VD4, VD5, VD6 - HER308; DA1 - L7812ABV; DA2 - L7805ABV; DA3 - TMV 0505D; DA4 - EL817; DD1 - ATmega328 DD2 - ATmega328; DD2 DD3 - IR4428; VT1, VT3 - BD139; VT2 - 2SJ585; TV1 - 220/140; TV2 - 220/12; TV3 - 1: 1; TV4 - MIT-4V; TV5 - TH60-220-50; HL1- BL- L515RGBW-CC;L1 - TGI2-400 / 16)

Controlling unit. Electric voltage is supplied to transformers TV1 and TV2 through the safety fuse FU1, where its value is reduced to 140 and 12 V respectively. It is applied to the diode bridges VD1 and VD2 with smoothing capacitors C1-C3 being located at their outputs. Resistor R1, which is connected through a normally closed relay winding K1, ensures discharge of capacitor C1 if construction is disconnected from the network. When the unit is connected to the network, a voltage of 12 V is applied to the coil of relay K1 and the resistor R1 is turned off, ceasing closure of the capacitors. DA1 linear regulator provides power to most of the circuit with a constant voltage of 12V. At its output DA2 microcircuit generates a constant 5 V for DA3 microcircuit which provides for galvanic isolation. The galvanically isolated part of the circuit contains the microcontroller DD1, which generates impulses and monitors condition of the lamp L1 (impulse thyatron). Buttons SB1-SB4 are required to set parameters of processing mode. Three-color LED HL1 indicates the current

condition of the installation: blue - records heating of cathode, which duration is up to 15 minutes, based on the passport data for the thyratron. Therefore, at this time, it is impossible to start generating impulses. Green indicates that the generator is ready for operation as the lamp has warmed up and the generator's switch-on is allowed; red indicates that the generator is working, control (igniting) impulses are received by the lamp. A two-line LCD monitor is used to display information. The monitor has 16 characters in each line. Transistor VT1, controlled by a microcontroller, sets the brightness of the display backlight. The output of the PB3 controller generates firing impulses with duration of $4 \mu\text{s}$, and the output of PB4 is responsible for connecting the thyratron grid to the circuit for generating high-voltage firing pulses. Before starting generating impulses, the microcontroller sends a signal to the optical coupler DA4. As a result transistor VT4 opens and current flows through relay K2 coil. After that a normally opened contact of this relay closes, thereby connecting the lamp grid L1 to the control impulse generation circuit. Then the process of control impulses' production begins. These impulses are supplied to the transistor VT3 and are transferred to a chip DD3 through an isolation transformer TV3, which controls a field effect transistor VT2. The transistor VT2 increases amplitude of the control pulses up to 200V and through the isolation transformer TV4 impulses enter the second block on the grid of the lamp L1.

Switching unit. In the switching unit, the system voltage is applied to the transformer TV5, where its value drops to 6.3V and enters the lamp L1. In order to prevent false triggering - opening the lamp L1 without control pulses - the grid of the lamp is connected to the "ground" via resistor R19 and disconnected from the ignition pulse generation circuit in the control unit. Capacitor C15 is needed to ensure that a constant voltage, which would not allow lamp to close, is not applied to the lamp grid. Once control pulses from the control unit are received, they pass through the capacitor C15, and, after getting on the grid, they open the lamp L1. As a result, the capacitive storage C16 discharges to the active load R_n , creating a pulse with a steep edge and an exponential cut (see Fig. 2). Closure of thyratron is possible with anode voltage totaling 300V.

High voltage unit. The main goal of this unit is charging of storage capacitor C16. The high-voltage unit consists of a fuse FU2, a laboratory autotransformer VT6, a step-up transformer VT7, a high-voltage resistor R20, a rectifier diode VD7 and a storage capacitor C16. Using a laboratory autotransformer, the voltage on the primary winding of the step-up transformer is changed to obtain the necessary constant voltage value of its processing after rectification by the VD7 diode. Resistor R20 is needed to limit the current charge rate of storage capacitor C16.

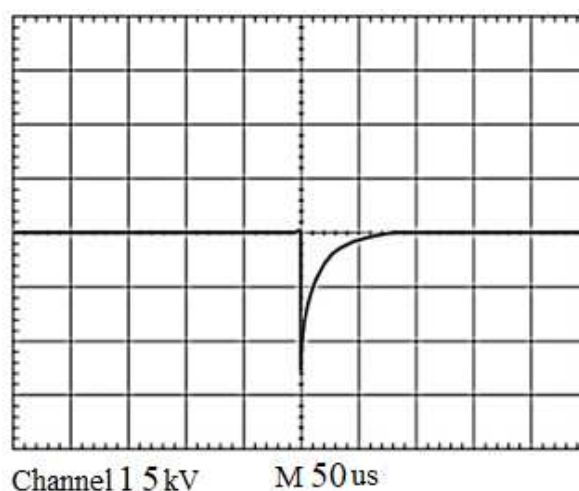


Figure 2. High-voltage impulse oscillogram: amplitude - 13 kV, front rise time - 300 ns; the duration of the exponential slice is 63 μs , the pulse duration is 65 μs .

Load. In principle, any object to high-voltage impulses can be treated as the load R_H of the designed generator. In our case, a working experimental cell was used as a load during a set-up. Both a

homogeneous mass of soil and soil containing dielectric inclusions (polypropylene objects resembling locust larvae in their shape and size) were processed in this cell. Structurally, the cell is a body of dielectric material and two plate electrodes, with processing samples being placed between them. The electrodes themselves are made of stainless steel so that the lower electrode is fixedly mounted in the frame, and the upper, spring-loaded, can move along the height of the cell, creating a fixed pressure on the processed soil mass.

3. Test results and discussion

The designed generator was assembled, tested, passed operational check and showed high stability as part of an experimental research complex aimed to study the process of electro pulse processing of soil mass samples in laboratory conditions. The complex structure includes (Fig. 3): a laboratory autotransformer, a high-voltage test transformer TWI 15/20, a digital multimeter MTX 3282, a high-voltage capacitor, a processing unit, a switching unit, a switching control unit, a precision LCR-meter LCR-820, a digital oscilloscope, a personal computer for analysis and data collection.

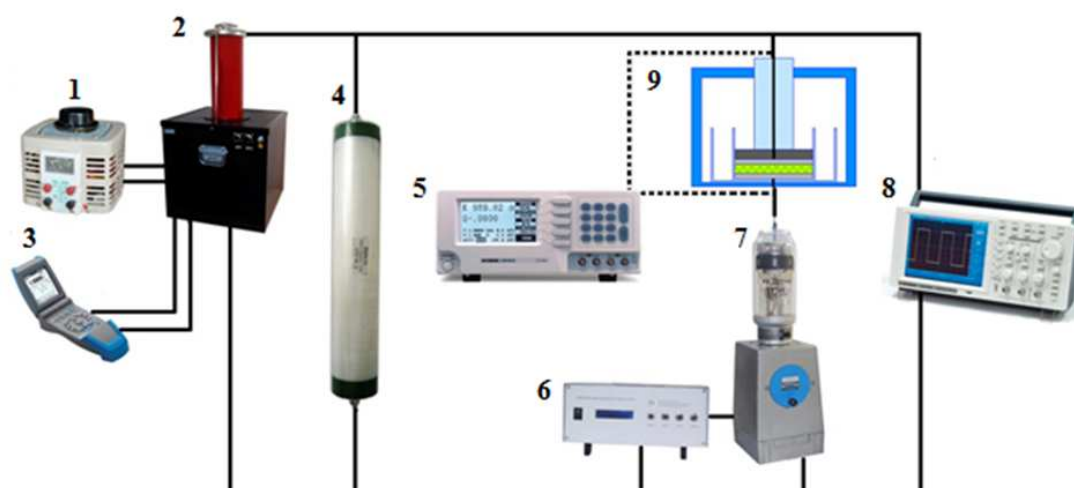


Figure 3. Scheme of an experimental research complex for studying the influence of electric impulse effects on the viability of locust larvae (1 - laboratory autotransformer; 2 - transformer high-voltage test TVI 15/20; 3 - digital multimeter MTX 3282; 4 - high-voltage capacitor; 5 - precision LCR-820 LCR meter ; 6 - switching control unit; 7 – switching unit; 8 - digital oscilloscope; 9 - working chamber with soil samples)

The processing chamber contains two working round electrodes, with one of them being rigidly attached to base of a collecting cup, and the other being movable and height-adjustable. The processed soil material is placed between these electrodes and pressed. Before starting processing, an LCR meter is connected to the electrode contacts and the initial resistance of the processing material is measured. Once the measurement is completed, the LCR meter is turned off and an output circuit – high voltage transformer, capacitor and switch are connected to the electrodes' contacts. Switch control unit allows you to set the required impulse repetition rate and their quantity. Capacitor's charge voltage value is set using a laboratory autotransformer according to an MTX digital multimeter's indicators, which is connected to a resistive divider of a high-voltage transformer. The processing proceeds as follows: the laboratory autotransformer is connected to the network and the necessary processing voltage is set according to the MTX digital multimeter's indicators. After that the necessary impulse repetition rate and quantity are set on the control unit, after which the controlling unit manages the switching unit and discharges the capacitor with the specified parameters on the soil volume located in the processing chamber. Once the process is completed, the processing chamber is disconnected from the high-voltage circuit and connected to the LCR meter to check the resistance of the soil sample that was

changed during processing. A digital oscilloscope recorded the change in voltage and current, and the data was saved on a personal computer.

4. Conclusion

Depending on the value of the processing voltage and the capacity of the output stage capacitor, research facility allows the following:

- 1) set the impulse repetition rate, which upper limits depend on the previously entered data, and the lower one is equal to the value of 1 Hz;
- 2) set the counter of the impulse numbers, which controls their generation when practicing a predefined algorithm;
- 3) generate high-voltage impulses with an amplitude of 16 kV with an exponential cut and various durations.

The capacitor of the output circuit is quickly discharged in the beginning, and then discharging becomes slower and slower, while the pulse forms a steep front and an exponential cut. The energy stored in the electric field of the capacitor is absorbed in the processed soil sample when discharged.

Oscillography of the impact voltage pulse and current impulse was conducted during the check of the working capacity of the designed construction of the impulse voltage generator. The impulses flow through the soil interval located in the working chamber between electrodes (Fig. 4). An analysis of the oscillograms shown on Fig. 4 shows that the soil volume is almost a purely active load, and this fact should be taken into account during subsequent studies when conducting experiments on soil samples containing locust larvae (egg capsules).

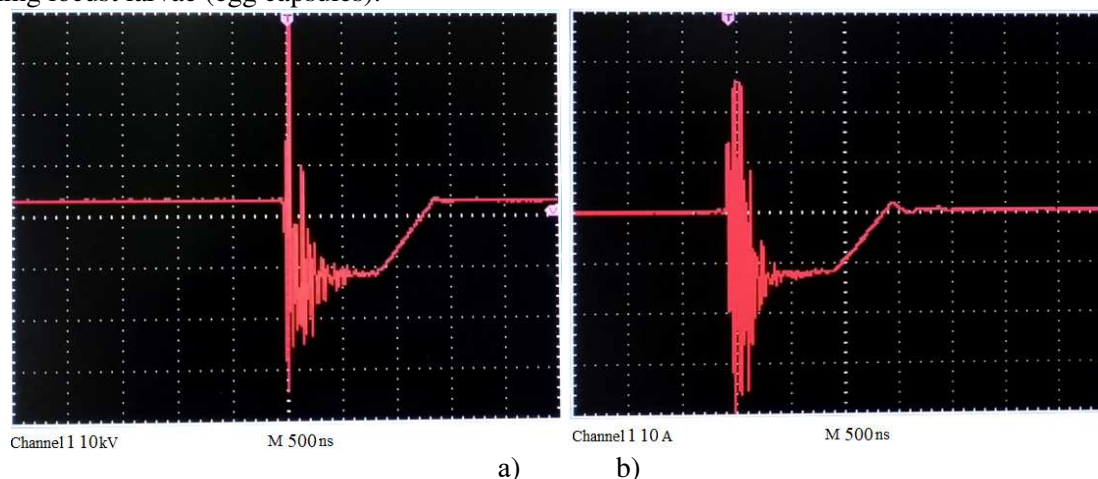


Figure 4. Oscillograms of the acting voltage impulse (a) and current impulse (b) flowing through the handled soil volume. The resistance of the soil volume in the working chamber, measured at a frequency of 10 kHz - 47.51 kOhm; and at a constant current - 81.48 kOhm.

The continuation of experimental research with a designed high-voltage impulse generator requires a detailed study and assessment of the amount of electricity to be used to cause irreversible damage to the locust larvae, influence of the input speed of electric energy, justification of the technology for combatting locust larvae and the technical solution for its implementation.

References

- [1] Yudaev I V, Shkrabak V S, Kokurin R G 2018 *XXVII international agro-industrial exhibition "AGRORUS-2018" (August 21-24, 2018, EXPOFORUM Convention and exhibition center, Saint Petersburg)* (Saint Petersburg: SPBSAU) pp 292-296
- [2] Korolev V A, Toporkov V N 2017 *Bulletin of agrarian science of Don* **3** 5-10

- [3] Baev V I, Yudaev I V, Petrukhin V A, Baev I V, Prokofyev P V, Armianov N K 2018 *Handbook of Research on Renewable Energy and Electric Resources for Sustainable Rural Development* (IGI Global) pp 283-310
- [4] Jeyamkondan S, Jayas D S, Holley R A 1999 *J. of Food Protection* **62(9)** 1088-96
- [5] Zhang Q, Barbosa-Carnovas G V 2001 *Lancaster: Technomic publishing company book* p 265
- [6] Stankovic M V, Cvijanovic M, Dukic V 2016 *Economics of Agriculture* **3** 861-870
- [7] Baev V I, Borodin I F 2002 *Electropulse pre-harvest treatment of sunflower and tobacco: monograph* (Volgograd: Stanitsa-2) p 231
- [8] Yudaev I V, Daus Y V, Gamaga V V, Grachev S E, Kuligin V S 2018 *Res. J. of Pharmaceutical, Biological and Chemical Sciences* **9(4)** 734-39
- [9] Lugovoy A V 1939 *Proceedings of VNIILH. Pushkino* **9** 93-102
- [10] Turlygin S Ya, Beklemyshev D S 1939 *Works VNIILM Pushkino* **9** 65-92
- [11] Peredel's'ke A A, Osipova L S, Efimov V N 1956 *Biophysics* **I** (5)
- [12] Tilvikas A A 1961 *Scientific works of the all-Union scientific-research institute of electrification of villages. resh farms. Moscow: Otd. Techn. resh information* **8** 134-149
- [13] Sklyar V T 1972 *Izvestiya TSKHA* **3** 179-185
- [14] Trofimova N B, Toporkov V N 1990 *Scientific and technical Bulletin on electrification of agriculture* **1** 29-33
- [15] Yudaev I V, Brenina T P, Prokofiev P V 2008 *Ecological and economic components of sustainable development of the region. Materials of the round table. Volgograd, 27.03.2008* (Volgograd: GOU VPO "Volga") pp 181-86
- [16] 2018 *Phytosanitary forecast of the spread and development of pests, diseases, and weeds on crops and land in 2018 and recommendations for their control in the Republic of Kalmykia* (Elista) 72 p
- [17] Yudaev I V, Moskvichev A Yu, Bityukov A A, Didyk V V 2011 *Izvestiya Nizhne-Volzhsky agro-University complex: Science and higher professional education* **3(23)** 26-33
- [18] Yudaev I V, Eviev V A, Romanyuk N N, Belyaeva B I, Muchkaeva G M 2019 Justification of the electric pulse method of locust control *International scientific and practical conference "Socio-economic and environmental aspects of the Caspian region development", may 28-30, 2019* (Elista: Publishing house of KalmSU) pp 442-45