The experimental results of the geophysical pulse voltage generator

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Abstract. The paper is devoted to the development process of the geophysical pulse voltage generator. The peculiarity of the generator lies in the non-specific purpose of this type of construction. Its main function is the controlled effect on the active faults of seismically dangerous zones. The results of the field experiment with the constructed device from 2018 to 2020 are presented. During the experiments, estimations and theoretical analysis we have obtained the seismic noise recorded by means of molecular electronic instruments and determined the periods of the electrical pulses. Operational parameters of the generator were identified on the basis of experiment results. The software and hardware elements of the system were upgraded and, as a result, a new version of the geophysical pulse voltage generator was developed.

1. Introduction
The paper studies the electroseismic effects in order to control deformation processes in geologic environment. A new type of external effects on earthquake source was found in the end of the last century in Russia, this is a simulated and natural electromagnetic effect on earth’s formations and crust in deformed condition. The experiments on stimulation of seismic events in Pamir and northern Tian Shan using a magnetohydrodynamic generator (MHD generator) are widely known [1]. However, the amount of electrical sounding on earth’s crust was reduced due to the high cost of MHD. Consequently, the Research Station of the Joint Institute for High Temperatures developed and constructed the thyristor assemblies EIS-100 (1983), EIS-300 (1984), EIS-630 (1986), ERGU-600-2 (1987) with their maximum currents reaching 100, 300, 630 and 1400 A respectively [1]. Considering the relevance of the experiments and the fact that equipment was made by special request, the Institute of Marine Geology and Geophysics (IMGG FEB RAS) started to develop its own construction for simulated electrical effect on seismic activity – the geophysical pulse voltage generator.

2. The first version of the pulse generator
The geophysical pulse voltage generator is a device that consists of two elements: a power source and a high-voltage commutator. The high-voltage commutator is a separate device and its main function is to stop/start the timed electric charge for affecting seismic activity. The core element of the commutator is an electric transistor switch. The transistors are used as an electrical switch is conditioned with the fact, that these electronic devices can be simply switched with low voltage pulses, that allows forming the pulses with the same on-off time. Insulated-gate bipolar transistor (IGBT) was selected since it is a fast-acting semiconductor device (switching time up to 200 ns) with
its power channel resistance low enough. It is capable of carrying a current up to 310 A at a voltage of 4 kV. The block diagram of the commutator is shown in figure 1.

A user adjusts the amount and on-off length of the pulses by means of the input device, which is constructed out of tact switches. A microcontroller (MC) receives and processes all the settings that are entered. The MC uses special software to switch on or off the IGBT according to the settings with a gate driver chip, which is intended to make galvanic isolation between analog and digital parts in order to make the scheme optimized and stable. The construction of the first version of the voltage commutator is shown in figure 2.

![User Input device Microcontroller Driver Transistor switch](image)

**Figure 1.** The block diagram of the commutator used in generating of electric pulses.

![Figure 2. The first version of the voltage commutator.](image)

![Figure 3. A set of batteries used as a power source in the experiments.](image)

A set of batteries (up to 30 rechargeable cells) connected in series was used as a power source (figure 3) of 300-400 V, that is not practical, but for the first experiment it could provide continuous current of 5 A or less, which met the requirements.

### 3. The first experiments

The first experiment was conducted in autumn 2018 on the proving ground of the complex observations «Karymshina» of the Institute of Cosmophysical Research and Radio Waves Propagation (IKIR FEB RAS, The Kamchatka Peninsula). Geophysical equipment of the complex observation station continually measures and records the parameters of the solar activity, magnetosphere, ionosphere, natural magnetic field of the earth and acoustic earth emission. Before the experiment, we used a molecular electronic hydrophone along with listed geophysical sensors in order to study its sensitivity to measuring the earth acoustic emission when the electric pulses are started. Instead of vertical earth electrodes, five-meter buried pipes of dry well were used with the distance of 35 meters between them. The experiment lasted for one hour, one hundred pulses were started with the on-time of five second and the off-time of thirty seconds. The maximum current determined was 0.9 A (figure 4). After the experiment the residual potential difference between the two electrodes was measured (Figure 5) [2].

During the experiment, the geophysical complex did not register the simulated electric pulses and a conclusion was made, that the current was not high enough to affect the seismic activity. It resulted in the reconstruction of the pulse voltage generator – the commutator parameters, its software and hardware parts were changed.
Further experiments were conducted in summer 2019 in geophysical observatory «Mihnevo» of the Institute of Geosphere Dynamics (IDG RAS, Moscow). The observatory studies the properties of the interrelated disturbance of inner and outer geosphere. During the experiment the peak current was up to 3.2 A. The result was achieved through increasing the amount of vertical earth electrodes to four and making the dipole length to 180 meters. However, the output data have not been published in open access so, there is no way to analyze the experiment results. Consequently, IMGG FEB RAS has purchased its own special wave recorder for molecular-electronic sensors in order to continue the experiments on Sakhalin Island [3]. In addition, there were disadvantages in using the set of batteries as a power source for the electric pulses: high cost and heavy weight, no air transportation, permanent maintenance of the construction since a drop of electromotive force (EMF) occurs, that negatively affects an experiment. The idea of using the set of batteries as a power source was rejected in favor of an AC-DC converter (figure 8) which was developed and constructed directly in the research equipment-sharing center of the Institute of Marine Geology and Geophysics. With small weight it is capable of converting the 220 V alternating voltage of 50 Hz into stabilized direct voltage of 360 V with maximum current of 4.2 A.

4. The experiment on the geophysical proving ground of IMGG FEB RAS

In 2020 the experiments have been continued on the geophysical proving ground of IMGG FEB RAS located in village of «Petrovlovskoe». A molecular electronic hydrophone MTAS-30 and a seismometer CME-6111 were used during the experiments in order to register the seismic changes [4-6]. We used a multi-electrodes system located on closely-spaced pits [7] to register the geoelectric processes in the near-surface part on the tectonosphere-atmosphere interface. A diesel generator as a primary source of the alternating voltage was used, and a developed AC-DC converter was connected to it in order to get the required direct voltage for the experiment. Four galvanized pipes of 2.5 meters long were used as earth electrodes with the dipole of 300 meters long. As a result, the peak current reached 5.5 A.
Figure 6. The envelope of the seismic noise signals of molecular electronic devices (top) and the change in the potential difference on the measurement channels between the electrodes of the northeastern (NE) pit of the geoelectric measurement system (bottom) during the experiment (UTC time).

The figure 6 shows that every phase of the experiment with the pulse generations and the resulting current in the outer layer of the earth’s crust matches the response recorded by molecular electronic sensors on the level of seismic noise. A-stage – two pulses started for the equipment checking. B-stage – the first pulse starts (polarity: electrode 1 (–), electrode 2 (+)), the pulse length – five seconds, the pause length – fifteen seconds, number of the pulses is one hundred, the current is 5.2 A at the start of the pulse and 4.95 A at the end. C-stage – the first series of the pulses ended. D-stage – planning to start the second series of the pulses (polarity: electrode 1 (+), electrode 2 (–)), pulse is not more than one second (failure to start the series of the pulses). E-stage – a test pulse to start the second series (polarity: electrode 1 (+), electrode 2 (–)), the pulse length is not more than 5 seconds (the generator overload occurred). F-stage – the second series of pulses (polarity: electrode 1 (–), electrode 2 (+)), the pulse length – ten seconds, the pause length – twenty seconds, the number of pulses is one hundred, the current is from 5.2 A to 5.4 A. G-stage – the end of the second series.

You can observe the obtained data more thoroughly in the work [8].

5. Developing a new version of the pulse voltage generator
Throughout the field experiments, the work of the first version of the voltage commutator was analyzed, the parameters and the modes were reconsidered, that was used to develop in parallel a new version of the device. The design of the new voltage commutator is shown in figure 7. It has an interface which consists of a matrix keyboard with an LCD display which is used to flexibly set the parameters and modes for an experiment, the power supply requires only one battery (the first version required three batteries to power the device), a graphite screening along with software and hardware solutions led to a better noise-immunity. The IGBT used in the new version is capable of carrying out a current up to 40 A with collector voltage of 1.5 kV.

The new version has three modes to choose: first to set the amount of the pulses, their on and off time, second to operate with the time of the experiment instead of the pulses counting – a user sets the time during which the device is working and the on and off time of the pulses, the software calculates the amount of the pulses to generate within the time range and starts the process, third mode is meant for test pulses before the whole experiment in order to check the parameters of the equipment.
6. Conclusion

As a result of the field experiments, observation, laboratory simulation and theoretical analysis which were carried out over the last four years, we developed and constructed the equipment of a new type for electrical sounding. The results of the experiments showed the general realization of the simulated electromagnetic effect on the active tectonic structure in real conditions.

The next phase of the experiment is the development of a network of seismological stations in Central Sakhalin Fault in order to monitor the seismic and trigger effects. In order to improve the quality of the values recorded by the geophysical equipment the current going through the dipoles must be increased significantly [9]. At present, the switching element of the geophysical pulse voltage generator is capable of carrying up to 40 A while the maximum current, which the power source can provide, is four times lower. This drawback can be solved by getting more powerful source or developing a set of voltage capacitors.

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