

Development of customized simulation models for high voltage generators

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Abstract. The article is devoted to the topical issue of using simulation modeling in the educational process of training specialists in the field of electric power industry and for the design of electric power networks. The issue of creating and using models of high-voltage test equipment is considered on the example of single-stage and multi-stage pulse voltage generators. The simulation models presented in the article can be used not only for educational purposes, but also for conducting research in energy systems.

Keywords: high voltage generators, simulation models, power networks

1 Introduction

The modern educational process associated with the training of specialists in technical areas in higher educational institutions cannot be imagined without the use of digital technologies.

Such technologies include multimedia tools, software environments for programming in languages of various levels, and electronic library systems. One of the most popular types of these technologies are software systems that allow simulation modeling.

The most widely used software systems for modeling electrical circuits are Matlab, ElectronicsWorkbench, Micro-Cap V, etc.

When studying high-voltage installations in universities in such areas of training as 13.03.02 "Electric power and electrical engineering" with training profiles "Electric drive and automation" or "High-voltage electrical power and electrical engineering", teachers are faced with the problem of lack of necessary laboratory equipment or the inability to use it in due to the lack of a qualification group for students, which allows work with a certain tension.

Simulation tools can be used to solve this problem. When using simulation models for educational purposes, it is possible to conduct experiments, the physical implementation of which is difficult or impossible even with the presence of special equipment.

This article presents an assessment of the possibility of using simulation modeling in order to implement high voltage generator circuits used in high voltage test installations.

It should be noted that the use of simulation and the Matlab program in particular, has proven itself well for solving various kinds of technical problems [1,2].

An additional advantage of the use of simulation models is the ability to quickly calculate transients in power supply systems [3,4,5,6] and electric drive [7,8], as well as during numerical experiments that provide a certain resource saving at industrial enterprises [9].

2 Simulation of a schematic diagram of a single-stage pulse voltage generator

As the first example of the developed simulation model of a high-voltage installation, the circuit of a single-stage pulse voltage generator with separated front and snubber resistors is shown in Figure 1.

The mathematical description of the operation of the presented circuit is as follows:

$$\begin{aligned} U_{C1} &= U_m(1 - \exp(-t/R_1C_2)) \\ U_{C2} &= U_m(\exp(-t/R_2C_1)) \end{aligned} \quad (1)$$

Resistor R3 plays the role of a vibration damper and eliminates the influence of the parasitic parameters of the discharge circuit.

This circuit is suitable for obtaining standard high voltage pulse shapes and for simulating the effect of these pulses on power plants.

Directly with the help of the presented model, at the Department of Physics, Biology and Engineering Technologies of the Murmansk Arctic State University, transient processes are simulated in electrical networks in the presence of lightning overvoltages.

The installation scheme is simple to implement, but it has a number of features. For this scheme, a graphical interface has been created that allows the user to change the settings of the links in the electrical circuit, as well as a block that simulates the change in resistance parameters in the circuit during prolonged operation of the installation has been implemented.

The MATLAB Function block changes the resistances R1-R4 after a while. The fact that such installations operate in short-term modes, in which there is no fundamental change in the resistance values from overheating, is not taken into account. This feature of the presented model is implemented for educational purposes, so that students have an idea of the influence of changes in parameters in power plants on the transient processes occurring in them.

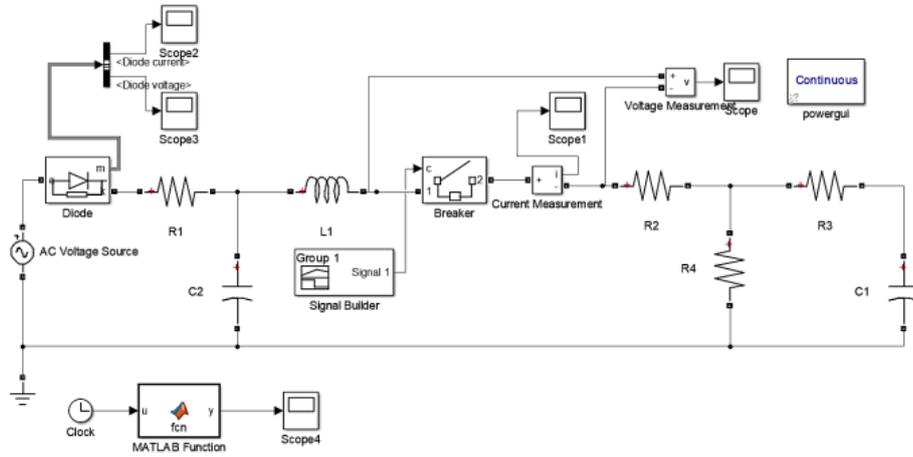


Fig. 1. Simulation model of a single-stage pulse voltage generator circuit with separated front and damper resistors.

With this model, it is possible to successfully obtain impulses of various shapes, for example: lightning impulses, switching impulses with oscillations, aperiodic impulses with single surges or superimposed oscillations.

Figure 2, for an example of the simulation result, shows a lightning impulse obtained using this model (upper graph) and also an aperiodic impulse with superimposed oscillations (lower graph). In this case, all the pulses that can be obtained using the model can have the necessary parameters, since the model has the ability to adjust.

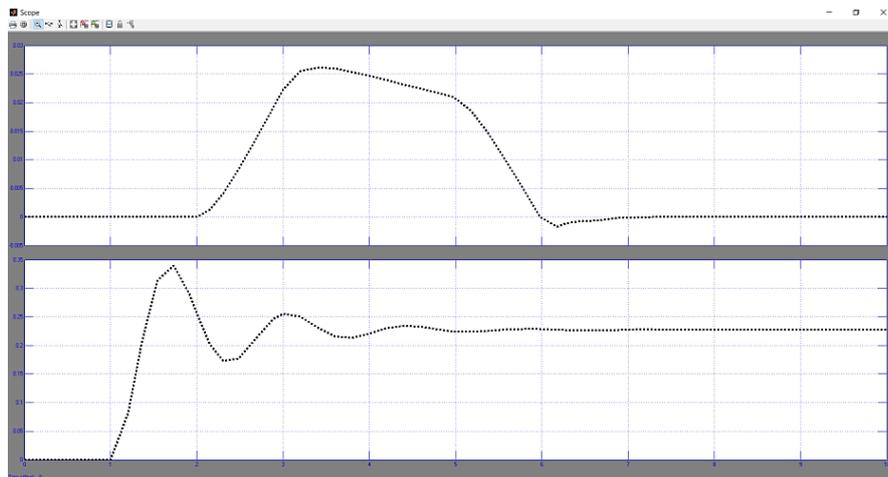


Fig. 2. Impulse voltage simulation results.

An important fact that prompts the use of such circuits is that the result of their work will be not just physical quantities, but numerical values of currents and voltage-

es. This contributes to the possibility of using previously designed circuits in models of large energy systems of high complexity, for example, as in [3].

3 Modeling the schematic diagram of a multistage pulse voltage generator

The second example presented for consideration in this article is the model of a multistage pulse voltage generator (MPVG). Such generators are used to obtain pulse voltages with an amplitude of up to several million volts, which completely excludes the possibility of their use in a training laboratory. This fact once again confirms the need to use simulation models.

The direct purpose of this device is to test the insulation of electrical equipment at industrial enterprises or in scientific laboratories. The training course for specialists in the field of electric power engineering includes training in disciplines related to the methods of selection and testing of insulation, and therefore the relevance of the developed model for educational purposes is high.

The scheme of this generator was proposed by the professor of Moscow University Vladimir Konstantinovich Arkadiev in 1914.

The model shown in Figure 3 shows a two-step scheme. In real MPVGs, schemes with several stages are used, but for modeling transient processes for educational purposes, two stages are sufficient. As in the previous example, users have the ability to customize the parameters of the model elements.

The circuit of the considered MPVG contains a structure of high voltage capacitors that provide high pulse voltages during discharge. Capacitors are switched using spark gaps (usually ball gaps). The Simulink application of the MatLab software environment lacks elements for modeling the spark gaps. The imitation of arrester operation was carried out using disconnecter blocks (Bracker).

The MPVG model includes an ammeter and a voltmeter as measuring devices, which make it possible to evaluate transient processes at the extreme spark gap.

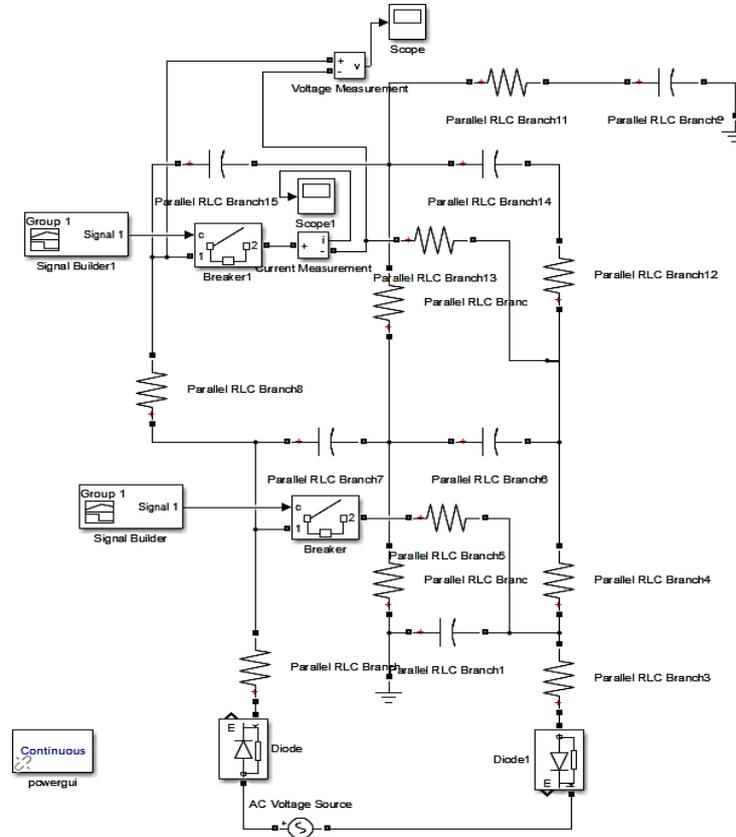


Fig. 3. Simulation model of a multistage pulse voltage generator circuit.

By changing the settings of this model, it is possible to obtain chains of pulses of any shape, which allows them to be used for the implementation of simulation models of other systems. The use of several models with modified block parameters is a clear example of demonstrating the influence of the parameters of the circuit elements on the form of the transient process. Figure 4 shows two transients obtained using the circuit in Figure 3, but with changed capacitor parameters.

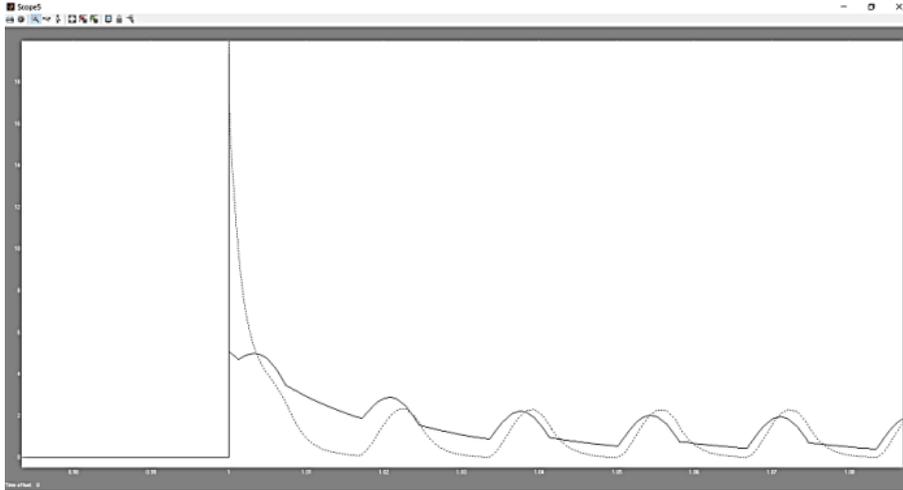


Fig. 4. Transient processes obtained using the multistage MPVG model.

The team of authors of this publication has developed a whole complex of models of test installations, which is successfully used in the educational and research process of the Department of Physics, Biology and Engineering Technologies of the Murmansk Arctic State University.

The list of developed models, in addition to various voltage generator circuits presented in this publication, includes models:

- single-stage rectification circuits;
- voltage multipliers;
- electronic voltage regulators;
- generators of impulse currents.

4 Conclusion

In conclusion, it should be noted that the use of simulation high-voltage electro-physical installations allows:

- avoid the use of equipment that for a number of reasons cannot be present in educational laboratories;
- carry out a wider range of experiments due to the ability to adjust the parameters of the model and simulate conditions that, when carrying out a real physical experiment, lead to equipment damage;
- improve the quality of teaching students, due to the ability to observe changes in the operation of models with a slight change in the settings of the blocks;
- to simulate transient processes in complex energy systems, not only within the educational process, but also in research and development and production.

In the future, the team of authors plans to form a library of developed and developed models.

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