

VIRTUAL ELECTROPHYSICS LABORATORIES: NEW GENERATION

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Abstract

Virtual Electrophysics Labs Complex has being presented in this article. The Labs Complex use a computer network grid to simulate some of High Power Electrophysical process, for learning and research purposes without huge amount of extremely expensive hardware. Integrated research environment are makes virtual reality of the real physical experiment and user friendly designed. General core of the Labs Complex is based on original software, encapsulated in Subsystems Models Library. The Subsystems are based on mathematical models and use tabular experimental data for simulating realistic physical devices features.

Key words

Virtual reality, programming, simulating, mathematical models, vacuum, powerful pulsed devices.

1 About Virtual Reality

It is well known [Lippman, 1980], that the term “virtual reality” was introduced in 1977 at the Massachusetts Institute of Technology (MIT) for the program Aspen Movie Map, simulating walk around the city using 3D models . Afterwards, the term has been widely used in various applications.

This technology is becoming more common in various areas of human activity. In some cases the attitude to these systems are not fully determined: the virtual corporation, virtual banking system, virtual currency, virtual office, etc. On the one hand the actual problem is the accuracy of the “true reality” or its virtual additions, on the other hand, study of issues related to the impact of information systems on the psyche and the adequacy of outlook of users is no less topical. However, virtual and additional reality computer systems have become more potential information components of scientific, educational and industrial technologies.

2 Virtualization in Electrophysics

The first Virtual laboratory of electrophysics: The “Vacuum Laboratory” was created on the department of Electrophysical Facilities of Moscow Engineering Physics Institute in the early 1970s before the first appearance of term in the technical literature.

Designed to date at the Department of Electrophysical Facilities complex of virtual laboratories [Averyanov et al., 2012], [Averyanov et al., 2009a], [Averyanov et al., 2009b] associated with the replacement of full-scale physical experiments on work at a screen with the program simulating of device. Simulator is an integrated model that includes both: a variety of traditional mathematical modeling and tabulated (experimentally obtained) data [Masunov and Polozov, 2004], [Masunov et al., 2007], the characteristics of real devices and subsystems, properties of the materials used, etc.

The development of such laboratories is caused by several reasons, including economic. These reasons complicate and sometimes exclude full scale experiments on real electrophysical devices in university laboratories. Among these reasons are the following features of electrophysical devices:

- Large variety of particle accelerators;
- Bulkiness of equipment;
- Radiation hazard;
- High voltage;
- Duration of the experiment preparation (getting high vacuum).

Appreciating the importance of a natural experiment and the work on real devices, it should be noted that computer modeling simulates the performance of individual component and subsystems of electrophysical facilities, it is a very useful and promising addition of experiments of Electrophysics. Despite the large number of different principles of acceleration of charged particles, the variety of types of accelerators, they all have essentially the same number of subsystems by which have developed virtual laboratories of electro-

physical devices. These systems include:

- Accelerating and focusing systems;
- Output devices and channels of transportation;
- Electronic monitoring and control system;
- Hi-power device pulsed technique.

Simulation of these systems is based on the corresponding virtual specialized labs of the department of Electrophysical Facilities. At the beginning, these laboratories had only learning orientation. Afterwards, due to the increase of functionality and accuracy of simulating will lead to the use of these laboratories in the design, configuration and analysis of individual elements and subsystems developed and existing installations.

We can distinguish two directions of development of these works:

- Extend the functionality of a full-scale modeling of existing laboratories (vacuum technology, electronic accelerator);
- Development of a fully computer (virtual) laboratories (complex of works on power pulsed technique, the study of dynamics and optimization of transport channels of relativistic charged particle beams).

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Virtualization of complicated technical systems, such as electrophysical devices involves the creation of computer-based integrated environment that simulate the impact on the system as a whole or on a separate subsystem and its real time response. Real system simulation behavior is implemented by a set of software models of physical devices. Unlike traditional software models, virtual model is simulate the same controls as the real device.

3 Current Realization Base Concepts

First of all in computer electrophysical labs design process, no attention was paid to the technological as-

pects of development of software systems and concepts such as open developing systems and structured programming and other software. In this regard, the modern development of software subsystems modules (SM) of virtual labs adhere to the following principles:

- SM should have portability to different environments (cross-platform);
- Have the property of extensibility - scalability;
- Subsystems must have a simple input language that does not require user knowledge of programming elements and adapting to the characteristics of operational environment;
- Input language should be as close as possible to the technique of physical experiment;
- Adaptation time to the corresponding applications should be as small as possible (no more than 5-10 minutes).

Structure of SM is built on the same principles and presented in interconnected blocks, modules may change during development independently to each other, the only requirement is support unified interconnect protocols.

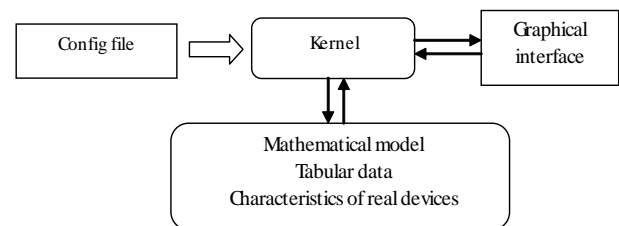


Figure 1. Adjusting panel

For mathematical models coding and unified interfaces of virtual labs used a cross-platform software development tools under a free license. This are GNU Compiler Collection (GCC) and Minimalist GNU for Window (MinGV), cross-platform software development tools in the programming language C++ Framework Qt graphics library with support and Web-interface of standard HTML5.

4 Realization High Power Pulsed Devices (PPD)

Although the above four virtual laboratories is associated with simulation of different physical processes, they have much in common. The greatest problem of full scale simulation is associated with PPD laboratory, on which example will consider the general structure and principles of work in virtual electrophysical installation (EPI) laboratories. The PPD laboratory is the complex, which includes two levels of devices:

1. PPD Basic Elements

- Lines of transfers with the distributed parameters (LDP) (LONG LINE application subsystem);

- Unrepresentative for a routine electrical engineering and an electronics engineering pulse transformers TRANS application subsystem.

- Subsystems of the universal appointment in practice of EPI the linear modulators and generators of high-voltage impulses with the rigid switchboard.

4.1 LONG LINE Subsystem Module

Among mathematical models of PPD devices the special place is taken by the LDP mathematical models used as forming devices for receiving short (picosec) impulses of big power, used in high current pulsed accelerators. For the solution of the telegraph equations describing processes in LDP, both analytical methods, based on Laplace transformations (for the homogeneous lines without loss), and finite-difference (net) methods (for the nonuniform lines with attenuation) were used.

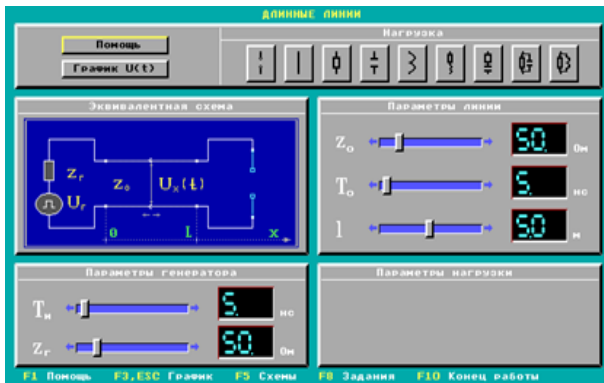


Figure 2. The adjusting panel

In fig. 2, 3 LONG LINE main user interfaces are presented. Adjusting (or tuning) panel (fig. 2) assembler of the scheme and choice of parameters of elements: generator, line, load. For research of influence of spurious capacitances and inductances on loading, and also

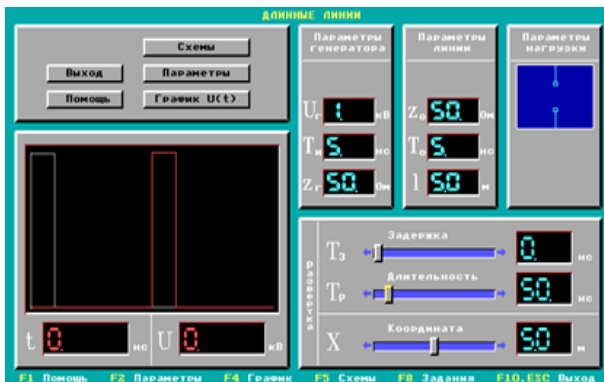


Figure 3. The measuring panel

for the solution of questions of matching line, generator and load.

The measuring panel (fig. 3) serves for the analysis of impulse on load at the chosen parameters of the scheme. The window imitates an oscilloscope by means of which it is possible to observe the digitized impulse and its separate parts with various extent of specification.

4.2 TRANS Subsystem Module

Transformation of signals is one of the operations which is most encountered in pulsed devices, allowing to receive the necessary voltage and current on load, providing coordination on power supply and load power.

SM TRANS application allows to consider the major factors defining a pulse shape, and also to choose the necessary parameters received from local model ratios. The package represents the simulator of two types of pulse transformers:

- traditional transformers with the lumped parameters in which models of formation of the front, top and a trailing edge on the basis of the corresponding equivalent schemes are used.
- transformers on lines with a variable wave resistance, specific for appliances of powerful pulsed devices where formation models in LDP are used.

In fig. 4, 5 the application package TANS main user interfaces are presented:

The adjusting panel (fig. 4) is intended for setting key parameters of the chosen transformer, entrance impulse and load.

The measuring panel (fig. 5) on which the user can adjust parameters of an oscilloscope sweep for signal research.

In fig. 6 the studied scheme, the equivalent scheme (calculated), and also the equivalent schemes for model operation of the front, top and a trailing edge are submitted.



Figure 4. The adjusting panel

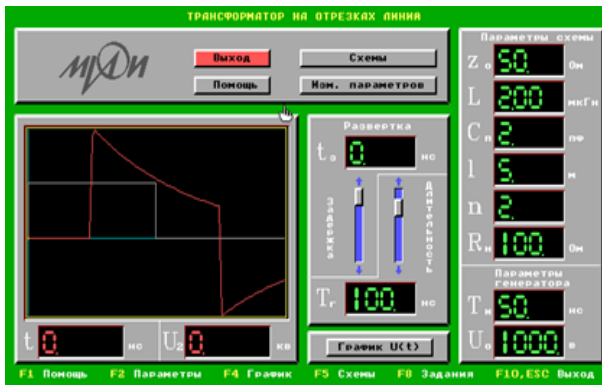


Figure 5. The measuring panel

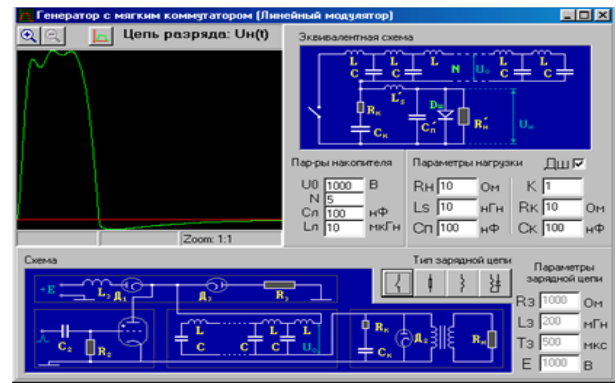


Figure 7. The adjusting panel and generator scheme

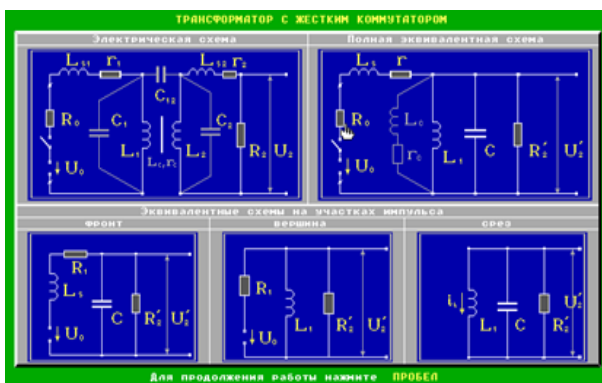


Figure 6. The equivalent schemes

4.3 GEN Subsystem Module

This SM is designed for the study of pulsed power generators of milli/micro second range. Powerful pulse generators, having a very large sphere of application, are subsystems of almost any particle accelerator. These devices are based on the template, which include previously submitted pulse transformers and forming lines. A key element determining the principle of functioning of the scheme of these devices is switchboard. All varieties of switchboards are reduced to two basic types: "hard switchboards" controlled by an electronic device, and fundamentally different from them "soft switchboards" on the basis of thyatrons, ignitrons, thyristors and discharges.

Subsystem GEN application allows studying the influence of these parameters on the characteristics of the pulse at the load in circuits with "hard" and "soft" switchboard.

Fig.7 presents combined adjusting instrumentation panel and generator scheme with a "soft" switchboard. Specifying the parameters of the generator scheme, the type of load and its parameters on the tuning of panel, one can study the impulse on load in convenient scale, using the measurement part of the panel.

5 Conclusions

With all the community of the principles of the organization and structure of the software each of Electrophysics Virtual Labs certainly has its own features, determined by the specifics of simulation and type of the user interface. The life cycle of these studies will depend of the development of computer technology: minicomputers with terminals, local networks of personal computers, global networks and web-based technology.

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