

# Using of Matlab Simulink for Education in High Voltage Technics and Electrical Safety

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**Abstract** – The using of contemporary methods for education in the area of high education enables for visualization of the studied processes and phenomena, increasing of the students' interest and improving their individual work. The paper presents MATLAB Simulink models for analytical research of the dangers from an electrical shock under normal and fault conditions of electrical networks low voltage at direct and indirect contact. Standard libraries and own models are used.

**Keywords** – MATLAB Simulink, Education, Electrical safety, High voltage technics.

## I. INTRODUCTION

The using of contemporary methods for education in the area of high education enables for visualization of the studied processes and phenomena, increasing of the students' interest and improving their individual work. A program product for visual programming (software package for modeling and simulating of dynamic systems Simulink from the system MATLAB) is used in this paper. The characteristics of researched systems are inputted in conversational mode by graphical drawing up of the scheme from the elemental standard blocks (units). As a result a model of researched system or device is received. The models can be easily built, parameters can be changed and the results from it can be immediately seen.

The processes arising under normal and fault conditions of electrical networks at direct and indirect contacts of a person can be visualized with the help of MATLAB Simulink.

This software package is very suitable for research of wave processes in power systems.

## II. IMITATION MODELS

### A. Imitation of electrical grids

Figure 1 shows imitation models for research of wave processes in case of wave's refraction and reflection in the node.

Imitation models include following blocks: distributed parameters line model (W1, W2), capacitance (C), inductance (L), wave model (Blok1, Blok2) and measuring devices for

voltages.

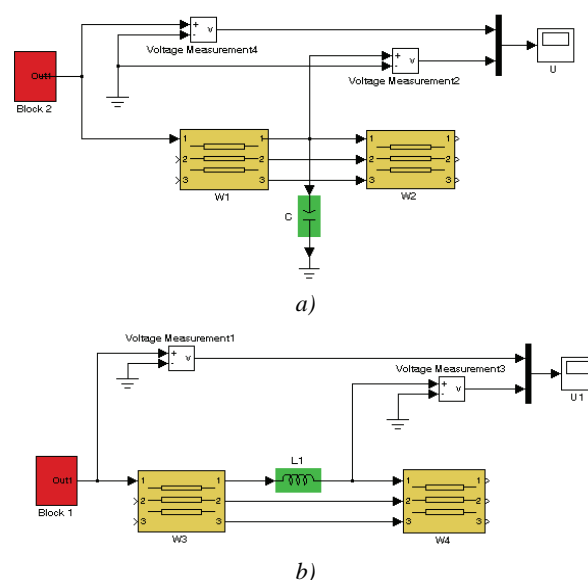


Fig.1. Imitation models for study of wave processes  
a) Capacitance in node; b) Inductance in node.

Imitation models of electrical grids low voltage type TN (TN-C, TN-S, TN-C-S), IT, TT are done. Standard libraries and own models are used [2]. Imitation models include following blocks:

- block System;
- Three phase transformer 20/0,4 kV;
- Same blocks model lines with different parameters;
- Block "Human body";
- Block or blocks "Load"- one or three phase loads;
- Measuring devices for currents and voltages;
- Earthing devices – of the neutral of transformer, for repeat earthing of the lines, for protection of the loads etc.

### B. Model of human body

The human body is modeled by following replaced scheme Fig. 2 (IEC 601-1 Medical electrical equipment, Part 1: General requirements for safety):

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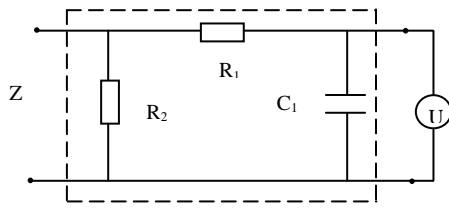


Fig. 2.  $R_1=10\text{ k}\Omega$ ;  $R_2=1\text{ k}\Omega$ ;  $C_1=0,015\text{ }\mu\text{F}$

### C. Research of wave processes in case of wave's refraction and reflection in the node

The traveling wave changes its shape and amplitude when it meets a heterogeneity. The wave that travels after the heterogeneity is called refracted and the returned wave – reflected wave. The point between the heterogeneities is called a node. The model schemes are developed [4] for research of wave processes in case of connecting of the different elements in the node.

Wave processes can be visualized with the help of model schemes given in the fig. 1 in case of wave's refraction and reflection in the node with connected a capacitor and a coil.

The capacitance and the inductance can be changed in the model and their influence over the amplitude and the shape of the incoming impulse wave can be observed.

An impulse overvoltage wave with amplitude of 60 kV, a front duration –  $1\text{ }\mu\text{s}$  and wave duration  $10\text{ }\mu\text{s}$  is modeled.

Fig. 3 and fig. 4 show exemplary results of the researches.

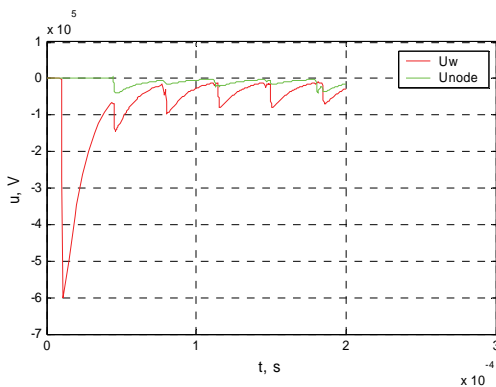


Fig. 3. Inductance in the node

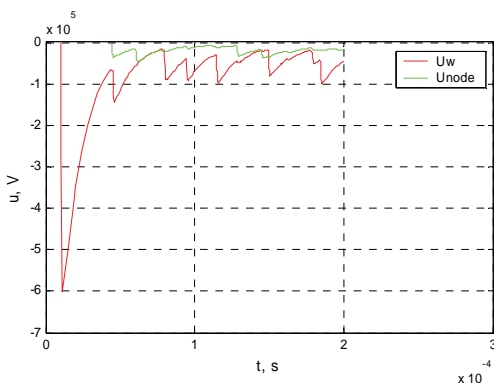


Fig. 4. Capacitance in the node

### D. Example of research in the electrical grid TT

An example of use of MATLAB Simulink for education in electrical safety is shown in the Fig. 5. It can demonstrate different cases of touches in the high voltage (20 kV) line and in low voltage (0.4 kV) line. Blocks of scheme are:

- Block System;
- Three phase transformer 20/0,4 kV with a grounded neutral;
- Blocks Line 1, Line 2 model three phase lines with different parameters;
- Blocks Line 3, Line 4 model one phase lines;
- Block "Human body" – according fig. 2;
- Block "Load" – one phase load;
- Measuring blocks for current via body and applied voltage;
- Earthing devices – of the neutral of transformer  $R_0$ , for repeat earthing of the lines  $R_r$ , for protection of the loads  $R_p$  etc.

This simulation model can visualize following cases studied in electrical safety:

- 1) Direct contact of a person to the phase conductor in the electrical grid HV under different work regimes of the neutral – a part of line between System and Transformer;
- 2) Direct contact of a person to the phase conductor in the electrical grid LV – a part of line between each two blocks Line 1 to Line 4;
- 3) Direct contact of a person to the phase conductor in the electrical grid HV and LV under different work regimes of the line (decreasing of the insulation's resistance, short circuit etc.);
- 4) Indirect contact in LV line under an insulation fault in the Load 1 and person's touch to the casing – Point 1;
  - Research of the effectiveness of the automatic disconnection of the supply in electrical grids TN – breaking of the connection with the earth resistance  $R_p$  and creation of a connection of the Point 1 with Neutral conductor of the line instead.
  - Research of the effectiveness of the protective earthing in electrical grids TT and IT. For electrical grid IT Transformer must work with insulated neutral.
- 5) The influence of the factors "Frequency" and "Voltage under human current" can be researched changing these parameters of the source.

### D. Other research

The students can model above mentioned situations by switching off and switching on of the different Blocks in the imitation scheme and can receive the results in graphical mode.

Fig. 6, Fig. 7 and Fig. 8 show exemplary results for same researched cases.

Fig. 6. shows the results for  $I_h$  and  $U_h$  at direct contact to the phase conductor in an electrical grid IT.

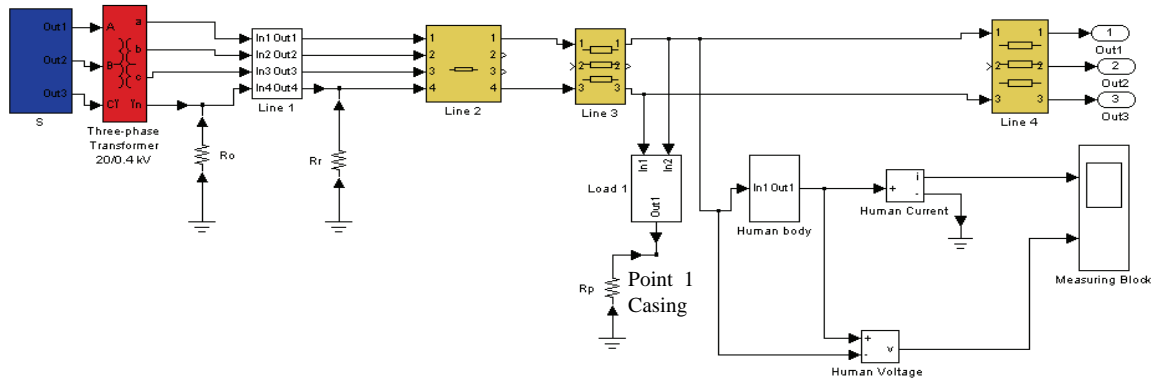


Fig. 5. An example of use of MATLAB Simulink for education in electrical safety

The results correspond to the accepted value of electrical resistance of human body  $R_h = 1000\Omega$ . Fig. 7 presents the results of the same case but with a value of  $R_h = 10^5$ , which value is more precise due to the applied voltage is low.

Fig. 8 shows the value of the current through the human body and of the voltage of the conductor PE ( $U_{PE}$ ). These results present the case when protective conductor is break down before the load under insulation fault. The presence of a repeated earth resistance after the load ensures a reserve way of a defect current  $I_d$ . The voltages of the conductor PE before and after the load are in phase opposition.

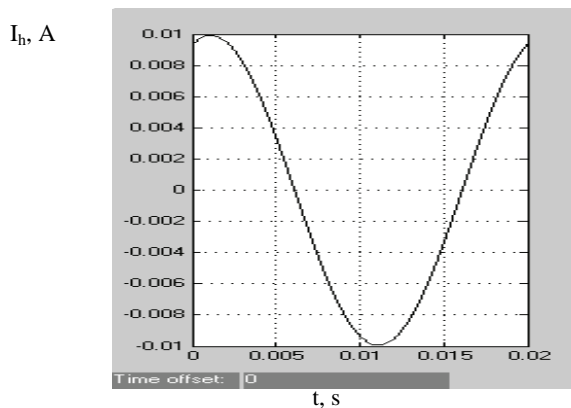


Fig. 6. Current trough a human body under direct contact in the system IT

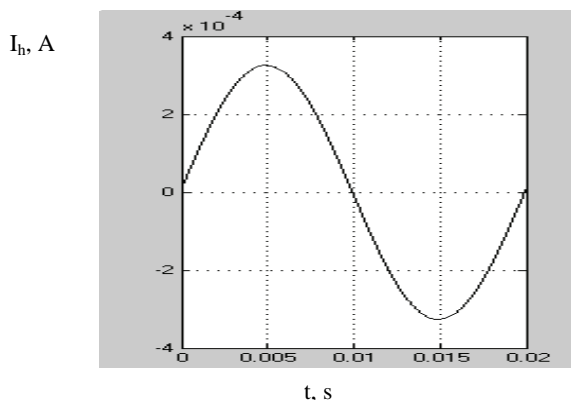


Fig. 7. Current trough a human body under direct contact in the system IT

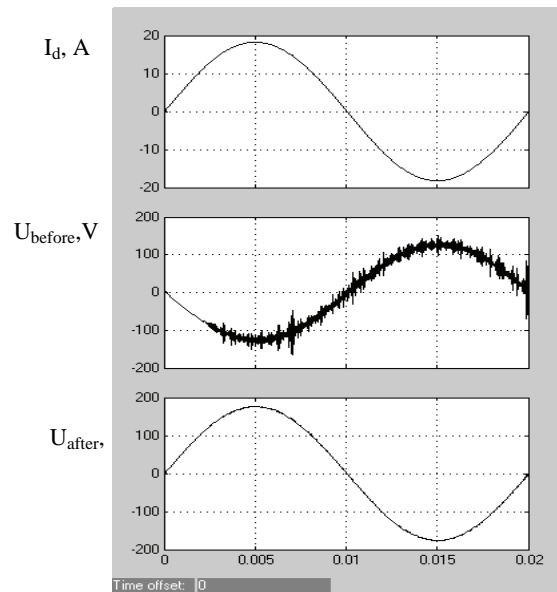


Fig. 8. The results from the research in the TN-S system

### III. CONCLUSION

The propounded method and the imitation schemes give the possibility on the students' own to research almost all possible situations of wave's refraction and reflection in the node and of direct and indirect contact and to do an evaluation of the electrical safety. It should improve their sound knowledge.

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