Concerning the Automatic Computation of the Electrical Stresses in the High Voltage Substations during the Transient Regimes

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Abstract - **This paper deals with an automatic computation program using a Matlab graphical user interface GUI useful to compute electrical stresses which appear in the high voltage substations; that means the parameters computation of the short circuit currents or transient recovery voltages which appear during the fault regimes in the high voltage networks. The numerical evaluation of the electrical stresses is carried out for the high voltage substations from ST Craiova such as transmission lines Filiasi, Slatina, Turnu Magurele, Isalnita. The parameters of the shortcircuit currents or over voltages are computed and graphical display of their variation in time can be available also. The influence of the high voltage network characteristics, such as the line length or the phase angle of the source voltage on the computed parameters level is pointed out. The Matlab GUI is developed based on the automatic computation program, which was achieved within the research contract with the Transelectrica SA Transport Branch Craiova. The partial results obtained within the above mentioned contract were previously presented in the various papers. Also, the computation algorithm is based on the results presented in the references of this paper. This GUI can be applied for any other high voltage substation whose rated parameters are known.**

Cuvinte cheie: *linii de distribuție de înaltă tensiune, regimuri tranzitorii, solicitări electrice, GUI Matlab .*

Keywords: *high voltage transmission line, transient regimes, electrical stresses, GUI Matlab.*

I. INTRODUCTION

In the electrical power system from the generation, transmission, distribution sectors many types of faults can appear having a strong impact on the economic losses or on the electrical equipment lifetime. The most frequently fault is the shortcircuit which can cause substantial damage to the electrical equipment. In order to evaluate electrical stresses produced by the shortcircuit it is important to compute the parameters of the shortcircuit currents and the switching overvoltage or recovery voltage.

A large number of failures in power networks are caused by internal overvoltages, whose values increase with increasing nominal voltage. The parameters of the switching overvoltages are the peak value or magnitude which depends on the parameters of the circuit, shape of variation in time, the frequency, the front time and the increasing speed or curve slope. The front time values of

this overvoltages can fall within the range 50-500 µs, which increase the initiation probability of the insulation breakdown.

According the IEC recommendations, the high voltage equipment must be designed and tested taking in to account the parameters of the switching overvoltages. One of the causes of switching overvoltages occurring is energization of a transmission line or the non load line commutation. When a high voltage transmission line is energized by switching the circuit breaker, the transients switching overvoltages are generated in the power network.

The parameters evaluation of the switching overvoltages is an important criterion to properly design of the equipment insulation from the high voltage networks. In the same time, considering the probabilistic behavior of the overvoltages occurrence, at insulation design must be also accomplished the economical requirements. As it is presented in [11] and [13] the parameters which affect the overvoltages are: source voltage, line length and closing time of the circuit breaker poles; finally, the purpose of the high voltage insulation design is to choose the right basic insulation level of the electrical equipment so that to accomplish the imposed failure rate criterion.

In the same time, knowing the parameters values of the short-circuit currents at any length of the overhead transmission lines it is very important to properly design the electrical equipment such as the circuit breakers. These equipment are subject to thermal and electrodynamic stresses, as long the fault persists until it's removed by acting the protective devices and circuit breakers. So, the fault must be detected and removed from the network, as quickly as possible to reduce the equipment stresses.

On the other side, in the high voltage electrical networks, the components parameters, such as the capacities of the transmission lines or the cables, the inductances of the transformers, reactance coils or generators can form oscillating circuits that can lead to the resonant phenomena. In these conditions the high voltage insulation is subject to dielectric stresses due to the resonant overvoltages which are temporary overvoltages [6]. That's why two important things are important: to determine the parameters of the circuit that would make resonance possible and the second one to determine the amplitude of the voltage at resonance or near the resonance phenomenon.

In this paper, is presented the computation of the parameters values of the short circuit currents and switching overvoltages, at different length along the transmission line and at different values of the voltage phase angle in relation to the occurrence moment of the fault, using a GUI Matlab. This paper presents an interface in Matlab based on the programs for the computation of the short circuit currents and transient switching overvoltages parameters. The interface can be applied for the lines from the Craiova North 220kV station, overhead transmission lines: Slatina, Filiaşi, Turnu Măgurele, Işalniţa and from the Tanţareni 400kV substation: Bradu overhead transmission line and Urecheşti substation.

The computation algorithms are based on the methodologies presented in the references in the field [6…12], which have been adapted to the specific values of the rated parameters of the analyzed transmission lines. The Matlab interface is designed in such manner to interact with the user so that to be applied for any other station or transmission line whose parameters are known.

The input parameters to automatic run the developed Matlab applications are: S_n– shortcircuit power of the power system which depends on the network impedance and network configuration, S_t – apparent power of transformer, U_{2n}– secondary rated voltage of transformer, U_{1n} – primary rated voltage of transformer, $u_{sc}[\%]$ – rated short circuit voltage, p_{sc} – rated short circuit loss, p_o – rated no load loss, i_o – rated no load current, C_1 – equivalent capacitance of transformer, s_{cond} – diameter of line conductors, l – line length, d_{ij} – distance between i and j conductors, R_0 – line resistance per unit length, C_0 – line capacitance per unit length, L_0 – line inductance per unit length. The output data after running the Matlab applicatios using GUI are the computed parameters of the shortcircuit current or the switching overvoltage according to the user selection. This computed parameters can be used to choose the right equipment to some wiring diagram or for the electrical equipment testing according to the standards and regulations in force.

II. THE MATLAB INTERFACE PRESENTATION

The automatic computation program developed in Matlab was described in the papers previously presented [4, 5, 6, 7]. In this paper is presented an improvement of the computation program through the developing a specific Matlab interface.

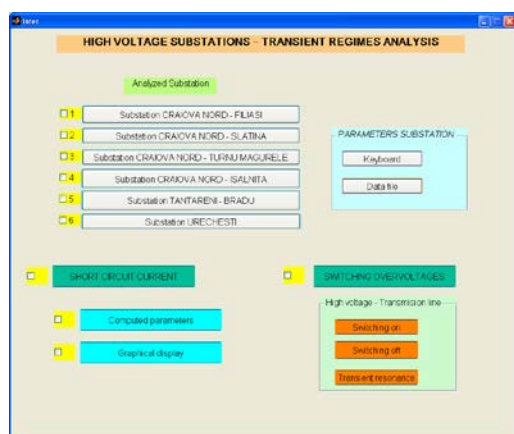The main interface of the Matlab is shown in the Fig. 1.

Fig. 1. The main interface.

This main interface allows to the user to choose the substation for which the computation of parameters is desired. As it can be noticed, these substations are: Craiova North 220kV - transmission lines Filiaşi, Slatina, Turnu Măgurele, Işalniţa; Tanţareni 400kV– transmission line Bradu and substation Urecheşti. The rated parameters of the selected high voltage substation can be input from the data file or from the keyboard. Input from keyboard can be an option when the user desires to use the developed GUI in order to compute the parameters corresponding to other substation than those which are presented in the interface presented in Fig. 1.

The presented GUI allows selecting the transient regime: the parameters computation of the shortcircuit current or of the switching overvoltages. In this last case, the user can select: the switching on, switching off regime of the non load transmission line or the transient resonance voltage. This interface allows to the user to select the manner of display of the computed parameters, meaning numerical or graphical display. Herein below it will be presented some cases to use the interface developed that is the subject of this paper.

Using the main interface, if the user selects: the substation Tanţareni – transmission line Bradu, the short circuit regime, the substation rating from the data file and numerical display of calculated parameters values, the results can be noticed, as it is shown in the Fig. 2. The rated parameters are: S_t=400MVA, U_{1n}=400kV, length line l=196.5km, R_0=0.0339Ω/km, C_0=1.0884.10^{-8}F/km, L_0=0.0010444H/m. The displayed computed parameters are: maximum short circuit current value - 9543Amax, RMS current value - 5581A, peak factor – 1.71.
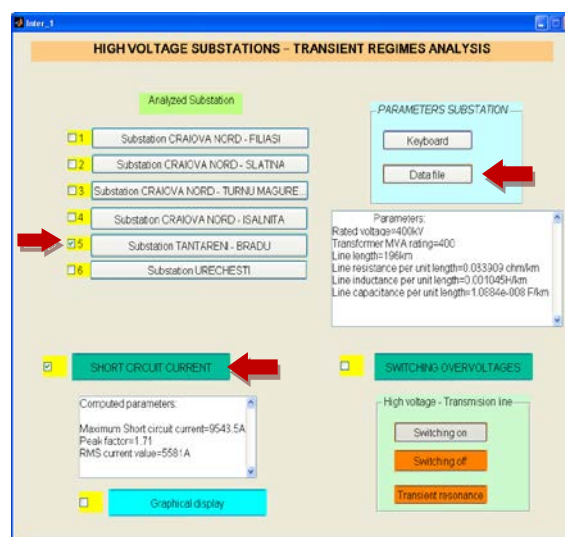

Fig. 2. The interface from substation Tanţareni, shortcircuit current regime, computed parameters numerical display.

In case of the Craiova North substation, transmission line Slatina, the interface is presented in Fig. 3. It can be observed that if the graphical display is selected, two graphics of the shortcircuit current variation, at different lengths of the line (l=1km, l=16km, l=36km, l=51km) and different phase angle of the source voltage (ψ=0, ψ=π/4, ψ=π/2) are displayed.
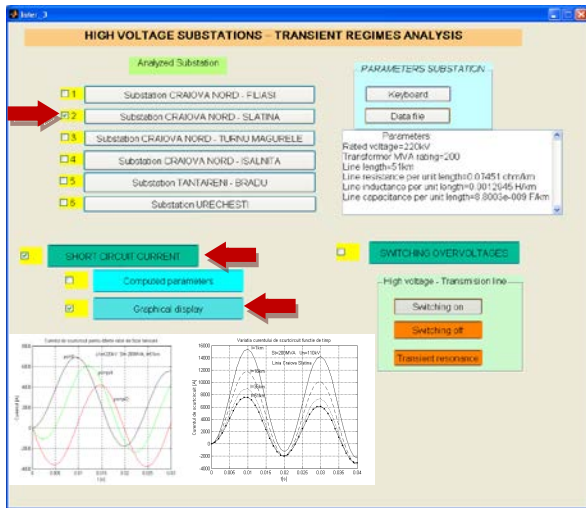
Fig. 3. The interface - Graphical Display - the shortcircuit current variations, substation Craiova North, Slatina transmission line.

Fig. 5. The interface - Graphical Display - Substation Craiova North, Slatina line, switching on overvoltage, no load line.

As it is expected, the maximum value of the shortcircuit current is lower when the initial phase voltage angle is $\psi=\pi/2$; as the line length increases, the peak value of the shortcircuit current decreases.

When the user selects the substation Craiova North, transmission line Slatina, the computation of overvoltages at the "switching on" of the non load line, the interface is shown in Fig. 4.

Fig. 4. The interface from Substation Craiova North, Slatina line, switching on overvoltage, no load line, computed parameters.

In case of the same selection, the graphical display is shown in Fig. 5.

In the left side can be observed the overvoltage variation in time, at the connecting of the no load line and without compensation and in the right side are shown the components variations of the same overvoltage.

If the user desire to select the substation Tanțareni, no load transmission line Bradu, then the displayed graphical variations will appear on the interface. This graphics correspond to the cases: the initial voltage phase angle is $\psi=0$ or $\psi=\pi/2$, will be displayed, as it is shown in Fig. 6, respectively Fig. 7.

From Fig. 6 can be determined the overvoltage computed parameters: peak value – 459.89 kVmax, peak factor – 1.81, time to the peak value – 0.0024s.
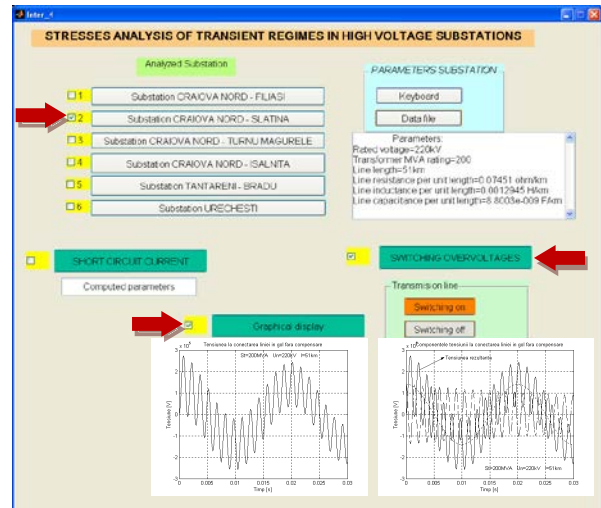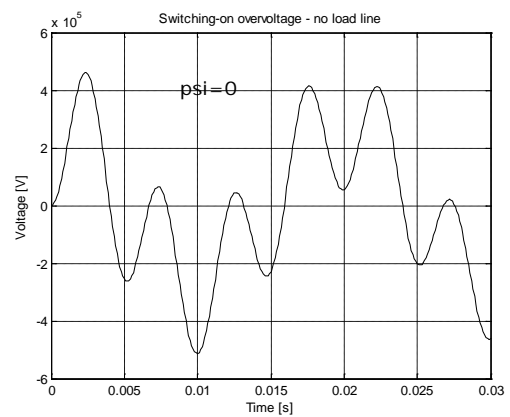

Fig. 6. Switching on overvoltage variation, $\psi=0$, substation Tanțareni no load line Bradu.
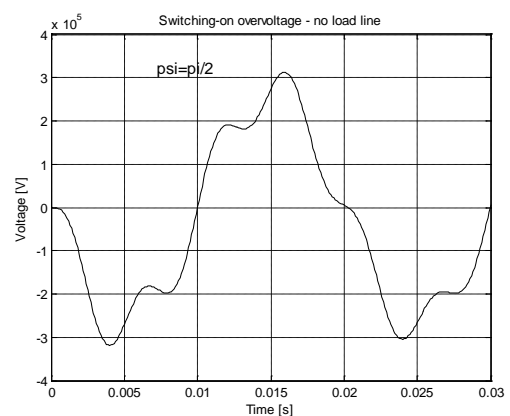

Fig. 7. Switching on overvoltage variation, substation Tanțareni no load line Bradu $\psi=\pi/2$.

In the same way with Fig.6, from Fig.7 can be determined the overvoltage computed parameters: peak value – 321.77kVmax, peak factor – 1.23, time to the peak value – 0.0159s.

To compute the overvoltage parameters at the line disconnecting, the "switching off" key is selected, after the substation and the way to input the rated parameters were chosen. For example, if the user selects the substation Craiova North, Filiaşi transmission line, l=36km, the rated parameters will input from the keyboard. The computed parameters of the overvoltage are: the overvoltage peak value at the beginning of the transmission line – 140kV with peak factor – 2.2, the overvoltage peak at the end of the transmission line – 251.36kV with peak factor – 3.92, as it can be noticed from Fig. 8.
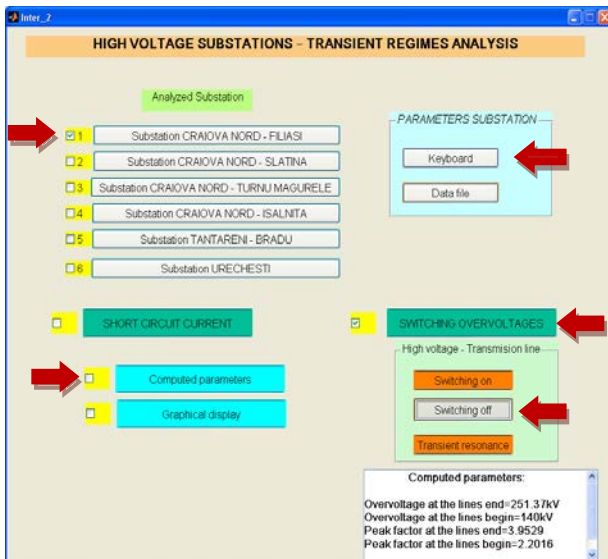

Fig. 8. The interface from Substation Craiova North, Filiaşi line - Computed parameters**.**

The variations in time of the overvoltages at the end of line and at the beginning of line are shown in Fig. 9 respectively Fig. 10.
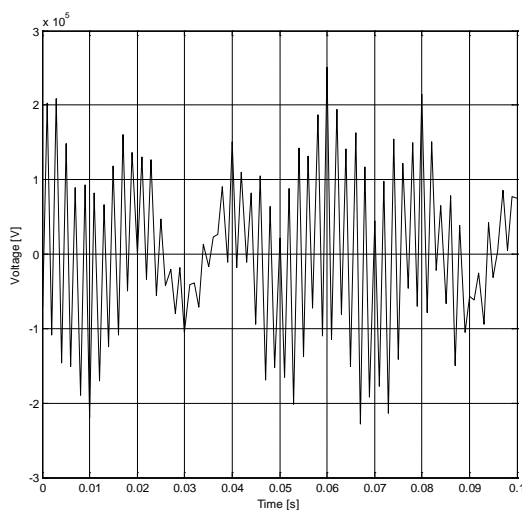

Fig. 9. Overvoltage variation at the end of line**.**

The last transient regime that can be computed using the developed Matlab interface is the transient resonance voltage.
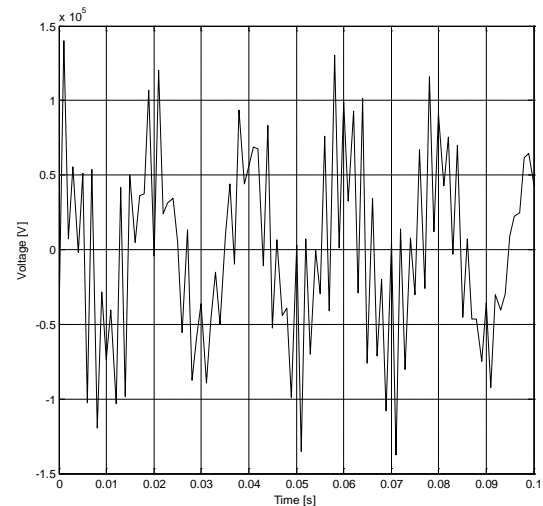

Fig. 10. Overvoltage variation at the beginning of line**.**

At the selection of the substation Tanţareni, transmission line Bradu, the keyboard input parameters, the numerical display of the computed parameters, the interface is presented in Fig. 11.
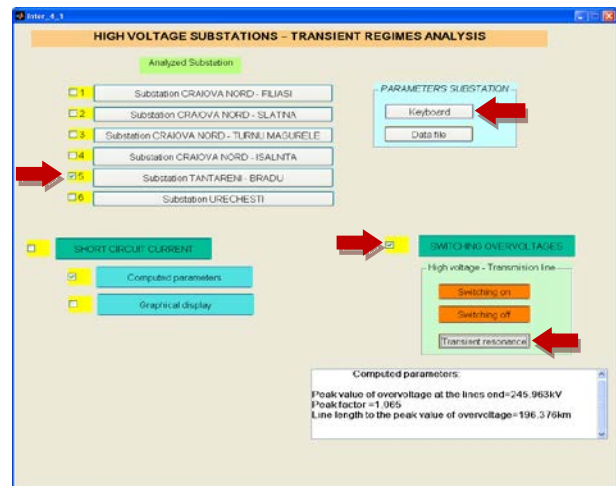

Fig. 11. The interface from Substation Tanţareni, Bradu line, transient resonance overvoltage. Computed parameters**.**

In case when for the same substation previously mentioned, if the graphical display of the resonance voltage is chosen, the results are shown in Fig 12.

In the left graphic it can be noticed the variation of the maximum value of the resonance overvoltage depending on the line length and in the right side is presented the resonance phenomenon at the theoretical 1491km length line.
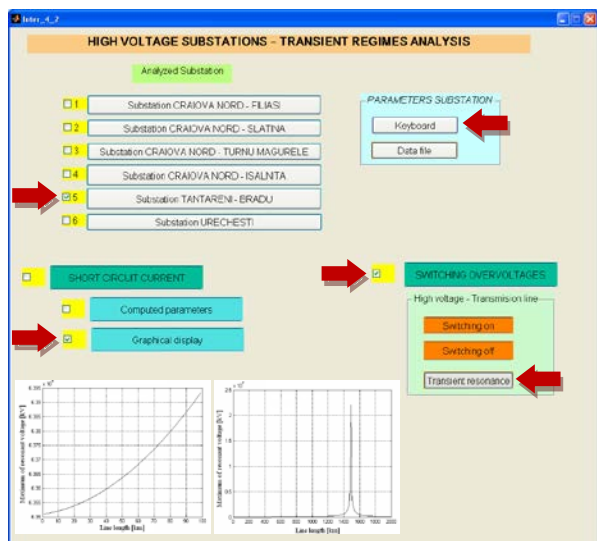
Fig. 12. The interface from Substation Tanțareni, Bradu line, transient resonance overvoltage. Graphical display**.**

III. CONCLUSIONS.

A Matlab interface, dedicated to the analysis of the electrical stresses of the transient regimes which occur in the high voltage substation, is presented. This graphical interface can be used to compute the parameters of the short circuit currents and of the switching overvoltages.

The computation parameters is applied for the high voltage substations from ST Craiova, for which the rated parameters are known. The main interface allows to the user to select the substation, the overhead transmission line, the manner to input the rated parameters. The selection of the transient regime: shortcircuit, switching on/off of the no load line or the resonance overvoltage, the manner to display the computed parameters are also possible to be carried out.

Knowing the parameters of the transient regimes is important in the designing process of the electrical equipment, the proper selection of the equipment from the high voltage substation and finally for their testing according to the European and national regulations in force.

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Contribution of authors:

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