SIMULATION OF ELECTRICAL LINES WITH DISTRIBUTED PARAMETERS IN THE PROGRAM DYNAST

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ABSTRACT

This article deals with possibilities of electrical lines simulations. Two variants of simulation are introduced and described. Next, the article deals with the issues of electrical lines simulations, structure and usage of these models in the program simulations. Processes of actives quantities for circuit with lumped parameters and for circuit with distributed parameters are introduced. At the end, simulations of impulse phenomenon propagation through a line with distributed parameters are shown.

Keywords

Dynast, overhead line, distributed parameters, impulse phenomenon, phase displacement

1. INTRODUCTION

Electrical lines are created from bar conductors or insulated conductors which are placed in the outside or inside areas. It is possible to simulate them in two ways. The decision whether to simulate the particular circuit by means of lumped or distributed parameters depends on geometrical proportions, rate of changes of electromagnetic field and the speed which the waves propagate through the circuit. The first method, which is the most common, is the simulation with the help of an equivalent circuit with the lumped parameters. In this circuit, there are individual physical properties represented by passive parameters like inductance, capacitance and other parameters. All these parameters create one circuit, where the voltage and current are independent on their location and time in the particular legs. In these circuits, the final speed of propagation of the electromagnetic field is not expressed. A real distribution of voltage and current is possible to follow only as one value for the whole circuit. This simulation is sufficiently accurate for elements, which do not achieve large proportions. In other words, it is there, where the geometrical proportions are negligible in comparison with the length of the wave. The second method of simulation is by means of a circuit with the distribution parameters. Physical quantities are represented again by the passive parameters and they are continuously distributed in space. Unlike the previous model, the particular currents in the legs and the voltages in the nodes are dependent on the location of legs and nodes and also on time. The final speed of the propagation of the electromagnetic field is expressed there. The process of voltage and current is possible to interpret as waves that go through the circuit at speed approximately as big as the speed of light.

2. SIMULATION OF LINE IN THE DYNAST PROGRAM

2.1. Structure model of line

Electrical lines are possible to simulate with the help of several different networks like Τ, Π, Γ which can have shunt leg at the end or at the beginning of network and by means of Steinmetz network. Each of them is accurate only to a certain size of the line length. The most accurate of them is the Steinmetz network, the least accurate is the Γ network. Because of this it is necessary to use this network for the simulation on the long lines. Each model consists of the longitudinal part, shunt part and the part, where there are mutual parameters. It depends on the simplified models and on the accuracy to achieve simulation results. Parameters such as resistance and internal inductance are placed in the longitudinal leg and they create series impedance. An earth capacitance and a leakage create the shunt admittance. Mutual parameters are defined among individual previous parameters in the individual phases. This structure is shown for gamma network in Fig. 1.

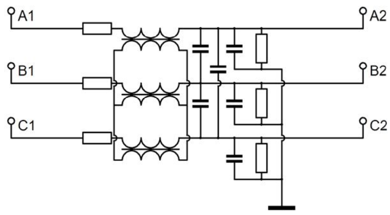

Figure 1 – An internal structure of the overhead line model in the shape of gamma network

2.2. Models of electrical lines in the Dynast program

In this program it is possible to simulate electrical lines in several ways. The methods are distinguished with regard to the operating parameters, real parameters, means values of parameters or the way they are entered into an appropriate model.

The operate parameters utilizing model
This model is the simplest in regarding of the amount of parameters. We can say that this model is useful for only informative simulations of steady state, because it does not respect real properties of the line. When simulating of transient states, results are significantly incorrect and therefore not useful for the next applications.

The real parameters with entering operating parameters utilizing model
In this model, operating parameters are entered by the user and then they are converted into middle values of real parameters in the desired ratio. The results that are retrieved in this model are corresponding to the reality. Therefore it is possible to use them for the next purposes. The disadvantages are constant ratio for the conversion of the operating inductance into the mutual inductance and also the operating capacitance into the earth capacitance and the capacitance among conductors. The model disrespects the real distribution conductors on the tower.

Model with entering the middle values of parameters
This model is also applicable for simulation processes, because results are accurate enough. The disadvantage is again in the entering of the middle parameters values.

Model with entering the real parameters
The most accurate simulations are got by this model. Individual parameters correspond to the real parameters here. Therefore it is the most suitable to use this model for the simulation of transient states. Its disadvantage is the need of the knowledge of appropriate sizes of real parameters.

Model with entering the middle values of conductors locations
If the user does not know the appropriate parameters and he/she does not want to calculate them, then this model is suitable. The necessity is the knowledge of the middle distance between the conductors and the middle height of conductors above the earth. The simulations that are executed by it are exact enough and therefore they are useful.

Model with entering of real construction parameters
Into this model the user includes the real parameters of conductor heights above the earth and also the real conductor distances. All the necessary calculations are executed by the Dynast program. The resulting simulations are the most accurate again. Its advantage is in utilization, when the user knows the exact construction parameters of the line.

2.3. *The line with the lumped parameters*

For illustration, there the simulation on the line is introduced with the lumped parameters and processes of the voltage at the beginning and the end of the line. The whole model is created from the symmetric voltage source, the overhead line on the voltage level 22 kV and the symmetric load of size of 100 Ω. The line is 20 km long and its parameters correspond with the conductor 210 AlFe 6. The configuration of conductors is horizontal with distances of 2x1.5 m and 1x3 m. The diagram of this circuit is in Fig. 2. The resulting voltage waveforms at the beginning and at the end of the line are shown in Fig. 3. It is evident, that the phase displacement of voltage at the end of this line is very small and the voltage drop achieves also small values.

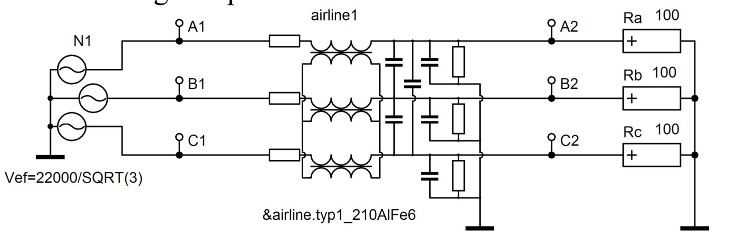

Figure 2 – The diagram of the circuit for line with the lumped parameters simulation

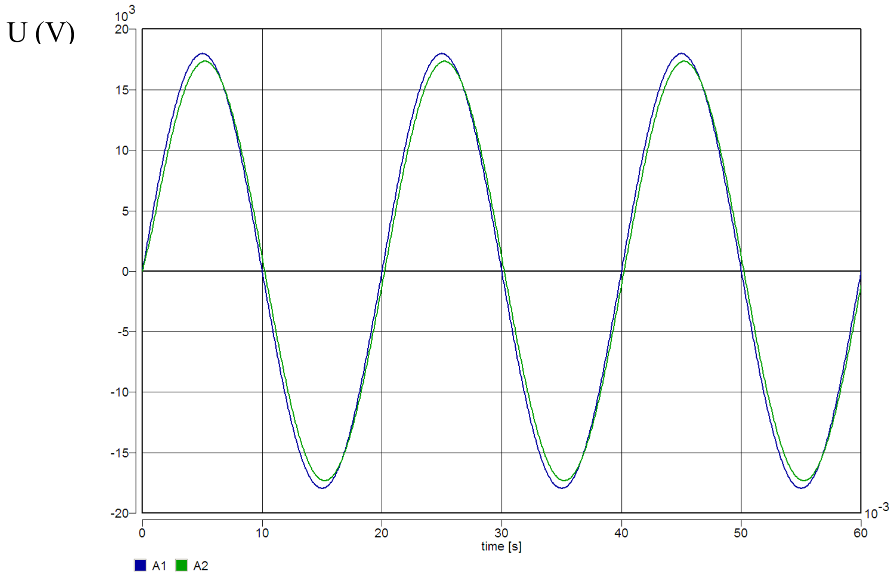

Figure 3 – The voltage at the beginning and at the end of the line for length of 20 km

2.4. *Line with the distributed parameters*

When all parameters are distributed equally along the line, this line is called a homogenous line. In case of the view of the elementary two-port at a certain point x from the start of the line and out of joint of the elementary line length Δx (Fig. 4), it is possible to write equations for this two-port.

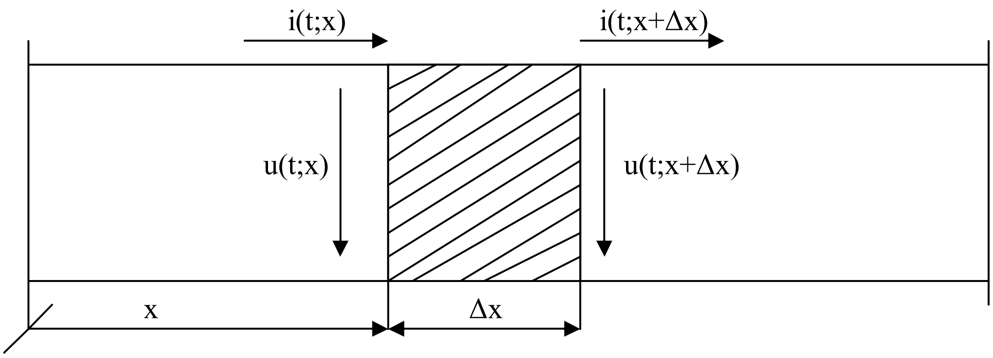

Figure 4 – Elementary two-port

After application of the first and the second Kirchhoff law it is possible to get the telegraphic equations. The longitudinal properties of the elementary two-port characterize parameters R and L, whereas the shunt properties describe C and G. This line is described by the telegraphic equations introduced in equations (1) and (2). Their conversion to the wave equation and the next modifications lead to equations that describe the current and the voltage distribution on the line for the proportion and the phase displacement (3), (4).

$$-\frac{\partial u(t,x)}{\partial x} = R \cdot i(t,x) + L\frac{\partial i(t,x)}{\partial t} \tag{1}$$

$$-\frac{\partial i(t,x)}{\partial x} = G \cdot i(t,x) + C\frac{\partial u(t,x)}{\partial t} \tag{2}$$

$$U(x) = U_p \cdot \cosh(\gamma x) - Z_0 \cdot I_p \cdot \sinh(\gamma x) \tag{3}$$

$$I(x) = -\frac{U_p}{Z_0} \cdot \sinh(\gamma x) + I_p \cdot \cosh(\lambda x) \tag{4}$$

Currents and voltages with an index p are at the beginning of the line. The parameter γ is the line propagation constant which is calculated according to (5) and Z0 is the wave impedance with its calculation in the equation (6).

$$\gamma = \sqrt{(R + j\omega L)\cdot(G + j\omega C)} \tag{5}$$

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} \tag{6}$$

In the Dynast program it is possible to simulate this issue simply. When using the physical diagrams of the lines, it suffices only the sorting of these models one after another. After the analysis of the transient states or the steady states it is possible to find how this long line behaves. In the figure 5, the diagram for this line is shown, which is composed from the five same parts. In the next figure (6), there are showed the voltage waveforms in particular nodes of the line. The particular lines are connected to these nodes. The simulation is carried out for the line, whose length is 250 km and it is represented by the operating parameters for the phase A.

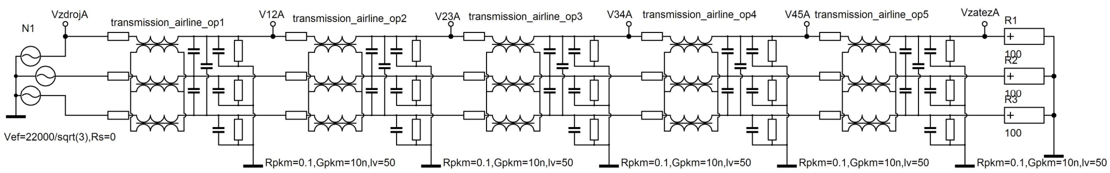

Figure 5 – Model of long line 250 km

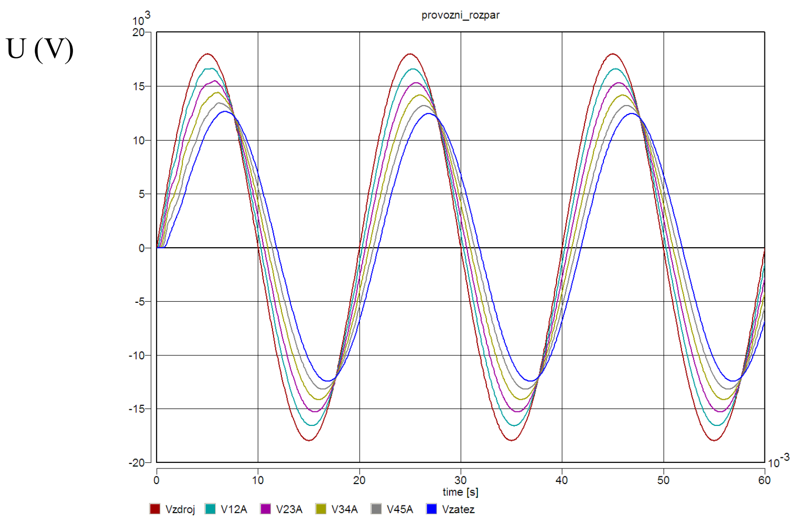

Figure 6 – The voltage distribution on the long line in the steady state

2.5. Impulse phenomenon on the lines

Due to the atmospheric discharges or the switching states overvoltage pulse waves can propagate in the electrical networks, which have harmful effect on the elements of the insulating systems. By the atmospheric discharges it is understood for example the direct lightning incidence to overhead line or its surroundings. These overvoltages are dangerous for the insulating systems of the distribution system. As a protection against the direct lightning incidence into the line, the overhead earth lines are used, which protect the line under the protective angle. The second way of the creation the overvoltage waves along the lines is influence of switching states, for example the switching off the unloaded transformers or the inside faults. During propagation of the overvoltage wave along the line it comes to the electromagnetic field losses by the radiation. These losses distort the original wave and the damping occurs on this wave. When the wave reaches onto the impedance interface, it comes to the transmission or the reflection in the same amplitude or the opposite amplitude. Because of these phenomena the voltage can increase many times in some line parts and therefore it can also to strain the insulating system very much.

The illustrative voltage proportions representation during the propagation of waves along the line is shown in the Fig. 7. The simulation circuit is identical like in Fig. 5, where the source which generates the voltage pulse in required parameters is substituted by the symmetrical source of voltage. This voltage pulse is superposed into the nominal harmonic voltage. The pulse parameters are the amplitude 1 MV, the pulse length is 10 ms and its time delay is 40 ms. The line is simulated by means of the model which respects the real physical parameters. For the possibility to follow these processes clearly, the resistance value is lowered to 0.002 Ω. The lengths of the particular line sections are 1 000 km. At the end of the line the load is connected to each phase in the size of 100 MΩ which respects the no-load state. From the simulation graphs is visible, how the waves propagate along the line and how it comes to the gradual pulse damping and energy adjusting processes.

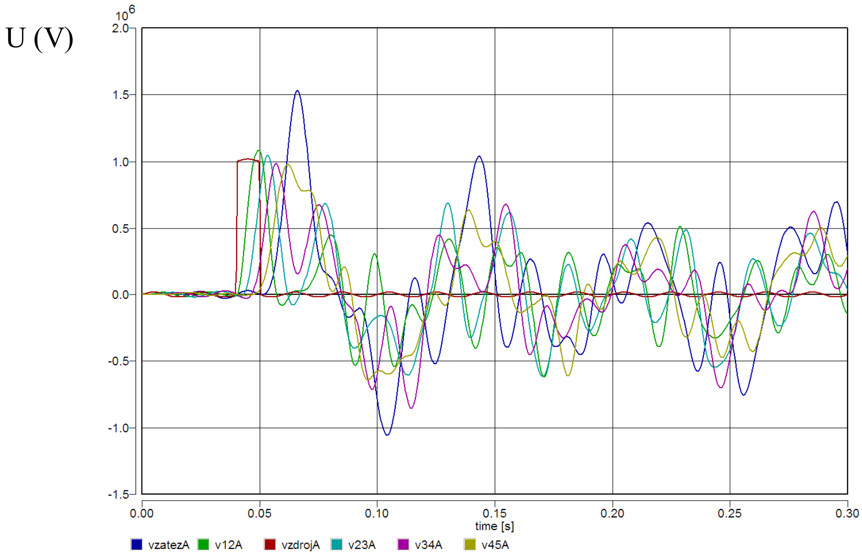

Figure 7 – The voltage pulse propagation along the line

In Fig. 8, the simulation of the similar arrangement is introduced, but with different power supply voltage. As the source the pulse voltage source is used with the parameters of 152 kV and length of its duration is 10 ms. The line sections are 50 km long and they respects the real parameters. The line is simulated in the no-load state. From the simulation is visible, how it comes to the pulse damping and also to the energy adjusting processes. Furthermore, it is visible waves propagation along the line can increase the voltage many times in the individual places.

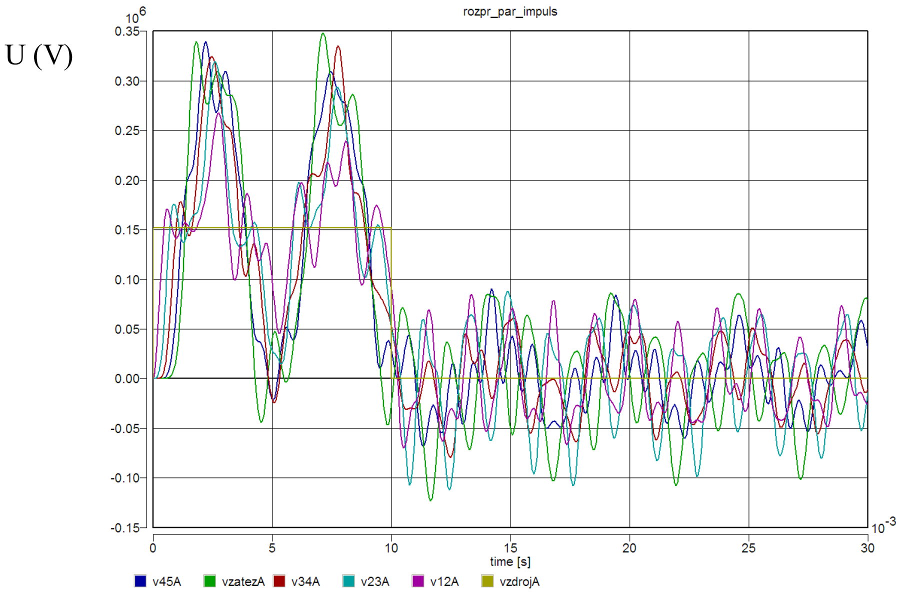

Figure 8 – The voltage pulse propagation along the line

3. CONCLUSIONS

The using of the simulation Dynast program is suitable for the monitoring of the steady states and the transient states on the electrical lines. When using the physical diagrams the identifications of the individual parameters or quantities is simplified for the user. With the advantage it is also possible to follow the propagation pulse phenomena and their influences which can to occur on the line. For these simulations it was verified that it is sufficient the usage of only common line models which use only standard differential equations. It is not necessary to create some special models whose outputs would be comparable. The advantage in comparison to other simulation means rests that it is not necessary to formulate complicated mathematical equations which would solve these phenomenon and the instruction formulating for the required quantities listing.

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