CALCULATING STABILITY OF NUMERICAL MODELS FOR CALCULATION OF OVERVOLTAGE AT COMMUTATIONS OF PROTECTIVE DEVICES

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Abstract

The given work is devoted to a choice of mathematical model for account of transient. For this purpose the following numerical methods of the decision of the ordinary differential equations were considered: Runge-Kutta method, Eyler method, method proposed by the Institute of Physics of National Academy of Sciences of Azerbaijan and multistage extrapolation methods proposed by G.Y.Kilukov and S.K.Shindin.

Thus was established, that method proposed by the Institute of Physics of National Academy of Sciences of Azerbaijan and multistage extrapolation methods proposed by G.Y.Kilukov and S.K.Shindin allows to settle an invoice transient at switching high-voltage circuits at presence of nonlinear resistance.

1. Introduction

In numerical electric transmission models, which main task is a reproduction of energetic characteristics of electric transmissions is usually limited by modeling of the simplest schemes of protective devices.

Mathematical description of such schemes can be divided into exact and approximate. Exact methods are based on programmed selection of logical or matrix operators of system of differential equations.

Approximate descriptions are based on replacement of protective devices with passive schemes, which parameters are changed at alteration of conditions of protecting devices.

The algorithm of modeling at using of inductive-active scheme of replacement provides for numerical integration of differential equations for protective devices' currents. At using of capacity-active scheme, system of differential equations of the model is increased due to equations for voltages of protective devices, but necessity in solution of algebraic systems is removed so the program becomes more flexible and compact [1].

2. The work description

For numerical solution of ordinary differential equations the following methods were considered: Runge-Kutta method, Eyler method, method proposed by the Institute of Physics of National Academy of Sciences of Azerbaijan and multistage extrapolation methods proposed by G.Y.Kilukov and S.K.Shindin [2]. Extrapolation methods are presently the most effective methods for numerical solution of ordinary differential equations. These methods enable to choose the best integration step and degree of method during solution of the task automatically and keep required accuracy of calculation. However existing theory of extrapolation methods has two serious shortcomings. Firstly it is based on the asymptotic decomposition of global error of one-step methods and therefore can not be used in the class of multistage formulas. Secondly, increase of degree of basic one-step method and specifying of numerical solution occurs due to repeated integration of initial task by basic method, but every time with more less step. Additional information obtained in such way enables to find some number of first terms in decomposition of global error of basic one-step method, and then use these terms for specifying approximated solution, increasing degree of basic method. Unfortunately such re-calculations of the solution for non-evident methods may cost sufficiently expensive.

At constant step this method can be compared with the method, proposed by Institute of Physics of National Academy of Sciences of Azerbaijan.

Apart from this, proposed methods for solution of ordinary differential equations of the first degree, the method of Kutta-Merson was considered. Indicated subprogram has some restrictions, which make difficult its effective usage at solution of the system of differential equations. Among them are 1) subprogram doesn't give a possibility to solve with its assistance in one program of several systems of equations; 2) number of equations in the system is limited and can't be more than 10; 3) in subprogram number of operators can be decreased; 4) number of arrays used in subprogram can be decreased from 8 to 6. These shortcomings were removed.

Subprogram is designated for step-by-step integration of system of ordinary differential equations of the first degree. In our case firstly the following scheme was considered fig.1:

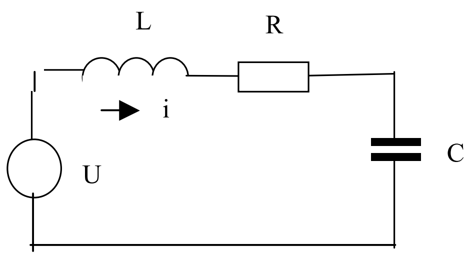

Fig.1. Calculate scheme

$$\begin{cases} \dfrac{di}{dt} = L^{-1}(U - Ri - U_c) \\ \dfrac{dU_c}{dt} = C^{-1} \cdot i \end{cases}$$

with given conditions: i=0; U_c=0.

There are not any difficulties in solution of this elementary task on the computer. However if scheme parameters are sharply different, i.e. ratio between L and C becomes quite essential, convergence at solution of differential equation is not provided. So integration step has to be decreased. But it's not possible at every time. For example, at solution of tasks with distributed parameters of equations of line it is necessary to have constant integration step.

We have used the method of Runge-Kutta of fourth degree, which has dominant application at numerical calculations [3]. Numerical solution of the task using method of Runge-Kutta is a construction of table of approximate values y1, y2, …, yn of the solution of equations y(x) in points x1, x2, …xn - knots of web. Let's use the system of equally-spaced knots. Value h -step of web (h>0).

Values yi+1 in this method are calculated under the following formulas:

$y_{i+1}=y_i+(h/6)(k_1+2k_2+2k_3+k_4)$,

$k_1=f(x_i,y_i)$, $k_2=f(x_i+h/2;\ y_i+hk_1/2)$,

$k_3=f(x_i+h/2;\ y_i+hk_2/2)$,

$k_4=f(x_i+h;\ y_i+hk_3)$.

Error of the method at one step of web is equal to Mh^5, but since it is usually difficult to assess value M at the practice, at error assessment Rugne's rule is used. For this purpose the calculations are m ade firstly with step h and then with step h/2.

If y_i- approximation, calculated with step h, and y_i (h/2) - with step h/2, the following assessment is correct.

$$\left| y_i^{(h/2)} - y_i(x_i) \right| \le \frac{16}{15} \left| y_i^{(h/2)} - y_i^{(h)} \right|$$

Method of Runge-Kutta is easily transformed to the ordinary systems of differential equations as

$$y_k'(x) = f_k(x, y_1, y_2, \ldots y_n), \quad 1 \le k \le n,$$

Using the system of program EXCEL the schedules of these associations were obtained.

However in some cases at calculation of recovering voltages at the switches' contacts, this method didn't provide stable solutions due to its insufficient accuracy.

As is known, ordinary differential equations with large numerical coefficients are poor for numerical solution. In tasks we solve large coefficients are connected with small or varying capacities of knot point, which registration is necessary at investigation of various processes, for example, in process of recovery of voltage at elimination of short-circuit. Institute of Physics has developed a method, which enables to obtain stable solutions for equations with coefficients of any value, as well as to solve common type equations at C=0.833E-9, L=0.133E-2, R=100, Δt=0.00001.

The results of these calculations are shown in the figure 2.

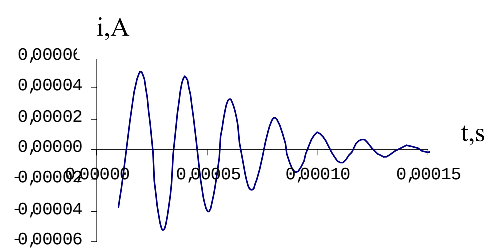

Fig.2. The results of these calculations

In view of considered elementary tasks of calculation of wave process in the difficult electric circuit, this task can be divided into elementary tasks of calculation of voltage and current in n equally-spaced points of electric circuit to the value of step h – intermediate points of electric transmission lines or in knot points of web. Consecutive solution of these tasks at one step in time gives the values of voltages and currents in equidistant points of web. Solution of these tasks step-by-step in time gives a picture of changing of voltages and currents in indicated points of the web.

The results of calculation of the system of ordinary differential equations by analytical method at C=0.833E-9, L=0.133E-2, R=100, Δt=0.00001 are shown in the figure 3.

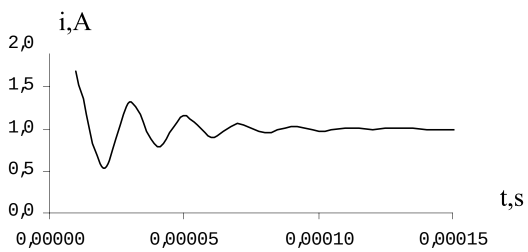

Fig.3. The results of calculation of the system of ordinary differential equations by analytical method

The circuit, where is connected shunting reactor and overvoltage limiter is resulted on fig. 4.

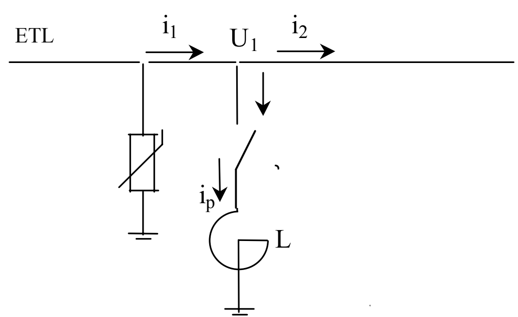

Fig.4. The circuit, where is connected shunting reactor and overvoltage limiter

Model of overvoltage limiter, recommended in IEEE, is given in the figure 5 [4].

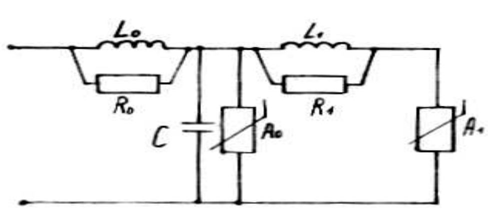

Fig.5. Model of overvoltage limiter

Thus, the offered model allows to settle an invoice transient at switching high-voltage circuits at presence of nonlinear resistance.

3. References

[1]. Джуварлы Ч.М., Дмитриев Е.В. Математическое моделирование волновых процессов в электрических сетях. Изд-во «Элм», 1975.

[2]. Куликов Г.Ю., Шиндин С.К. О многошаговых экстраполяционных методах для обыкновенных дифференциальных уравнений //Доклады Академии Наук, 2000, том.372, №3, с.301-304.(Russian).

[3]. Березин Н.С., Жидков Н.П. Методы вычислений, ч.II, «Высшая школа», 1962. (Russian).

[4]. IEEE W.G.3.4.11of Surge Protective Devices. Committee –Modeling of metal oxide surge arresters. – IEEE Trans. on Power Delivery. Vol.7.No.1.January 1992.-P.301-309.