

# Research and Development of Graphical Transient Calculation Software for Gas Insulated Substation

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**Abstract**—On the basis of object oriented program (OOP) technology a method for developing transient calculation software for Gas Insulated Substation (GIS) is presented in this paper. The software is based on the graphical interfaces, and graphical component is designed according to electric main wiring diagram for primary system and is automatically converted to transient simulation model for satisfying the demand of field operating personnel. In this paper design principle and functions are described, and the calculation result is testified by the experiment at last.

**Keyword**-transient calculation; object-oriented; graphic system; power system; main wiring diagram

## 1. Introduction

Since the 1960s, Gas Insulated Substation has been widely used in power system because of their excellent properties such as small occupied area, free from environmental influence, reliable operation, and small maintenance. But Very Fast Transient Overvoltage (VFTO) [1] is generated during disconnecter or breaker operation in GIS. With the increased voltage level of GIS, VFTO has an increasingly serious damage and arouses a great attention among research, design, construction and operation workers, and a lot of research has been done.

Application of digital computer on power system transient overvoltage calculation has many advantages like fast calculation, strong applicability, convenience for use, high accuracy and thus become the most important overvoltage calculation tool for the moment [2]. But, the present transient overvoltage calculation software such as EMTP, EMTDC [3], mostly need operator to master solid transient modeling theory [4] of electrical equipment, which causes the field personnel so much inconvenience in use. Therefore, GIS transient program (GISTP) is developed on the basis of the developing platform Microsoft Visual Studio 2008, Object-Oriented technology, and C# of Microsoft. The software tries to be friendly interface and easy to use, provides a feasible solution for field operating personnel who calculates transient overvoltage of GIS.

## 2. Brief Introduction of Bergeron Method

Bergeron method which is effective solution for transient overvoltage calculation in Power System is adopted to program calculation procedure of the software. Its calculation process is as follows: Firstly, distributed parameter line and lumped parameter elements ( $L, C$ ) are substituted with a equivalent resistance and current source (its value is obtained by historical data record of voltage and current across the element). Secondly, node voltage in the case of every time step is calculated from a general method which is used to solve resistive network. Finally, transient solution of the network is gained [5].

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## 2.1. Bergeron Model of Lumped Parameter Elements

Bergeron models of inductance and capacitance can be deduced by utilizing trapezoidal integral formula. Transient calculation formulas of inductance  $L$  and capacitance  $C$  are respectively shown in formula (1), (2).

$$i(t) = I_L(t - \Delta t) + \frac{1}{R_L} u(t) \quad (1)$$

$$i(t) = I_C(t - \Delta t) + \frac{1}{R_C} u(t) \quad (2)$$

where  $I_L(t - \Delta t) = i(t - \Delta t) + \frac{1}{R_L} u(t - \Delta t)$ ,  $R_L = \frac{2L}{\Delta t}$ ,  $I_C(t - \Delta t) = i(t - \Delta t) + \frac{1}{R_C} u(t - \Delta t)$ ,  $R_C = \frac{\Delta t}{2C}$ .

Therefore, equivalent calculating circuit models of inductance and capacitance are shown in Fig.1, differ only in concrete implications of resistance  $R$  and current source  $I$ . And the model of resistance is resistance itself.

## 2.2. Bergeron Model of Lossless Transmission Line

Transmission line is shown in Fig.2(a), the length is  $l$ . Making use of traveling wave theory of transmission line, formula (3) and (4) are obtained. Where  $\tau = l/c$ ,  $c$  is speed of light. Equivalent circuit of transmission line is shown in Fig.2(b).

$$\left. \begin{aligned} i_{km}(t) &= \frac{1}{Z} u_k(t) + I_k(t - \tau) \\ i_{mk}(t) &= \frac{1}{Z} u_m(t) + I_m(t - \tau) \end{aligned} \right\} \quad (3)$$

$$\left. \begin{aligned} I_k(t - \tau) &= -\frac{1}{Z} u_m(t - \tau) - i_{mk}(t - \tau) \\ I_m(t - \tau) &= -\frac{1}{Z} u_k(t - \tau) - i_{km}(t - \tau) \end{aligned} \right\} \quad (4)$$

## 2.3. Application of Bergeron Method

As is shown in Fig.3, there is a no-loading transmission line between 2 and 3 node,  $e(t)$  is power frequency voltage source,  $Z$  is wave impedance of transmission line,  $\tau$  is propagation time,  $R$  is internal resistance of source, and the switch is closed at a certain time. Equivalent circuit model of the network is shown in Fig.4 based on Bergeron method. By making use of node-voltage method network equation (5) is obtained.

$$\begin{bmatrix} \frac{1}{R} + \frac{1}{R_L} & -\frac{1}{R_L} & 0 \\ -\frac{1}{R_L} & \frac{1}{Z} + \frac{1}{R_L} & 0 \\ 0 & 0 & \frac{1}{Z} \end{bmatrix} \begin{bmatrix} u_1(t) \\ u_2(t) \\ u_3(t) \end{bmatrix} = \begin{bmatrix} \frac{e(t)}{R} - I_L(t - \Delta t) \\ I_L(t - \Delta t) - I_2(t - \tau) \\ -I_3(t - \tau) \end{bmatrix} \quad (5)$$

Because the circuit is in the zero state before closing, initial values of  $I_L(t - \Delta t)$ ,  $I_2(t - \tau)$ ,  $I_3(t - \tau)$  are zero on the formula (5). The key to solving formula (5) lies in updating the values of  $I_L(t - \Delta t)$ ,  $I_2(t - \tau)$ ,  $I_3(t - \tau)$ . According to the physical meanings of Bergeron model of every element, the value of current source is updated by using the formulas which are described in section II(A) and II(B). Therefore, node voltage in the case of every time step is obtained until requirements are met. The whole calculating procedure is shown in Fig.5

## 3. System Design and Function Realization

Object oriented technology (OOT) [6] is a kind of new principal programming method which attempts to imitate people to build the model of the real world. The technology makes the object and feature of real world

correspond with the class and method of computer model, which guarantees good readability and maintainability. Power system is composed of various physical components, and the relative independent attribute of each component and the characteristics of the connection between components are particularly suitable for object-oriented management mode [7].

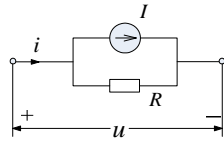


Fig.1. Model of lumped parameter elements

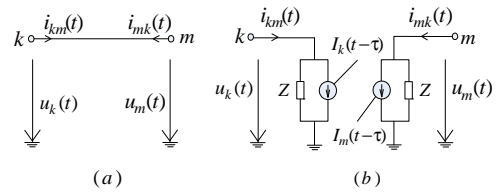


Fig.2. Archetype of circuit and equivalent circuit

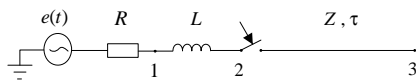


Fig.3. Network structure

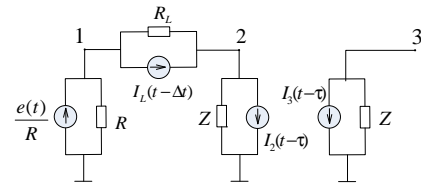


Fig.4. Transient equivalent circuit model

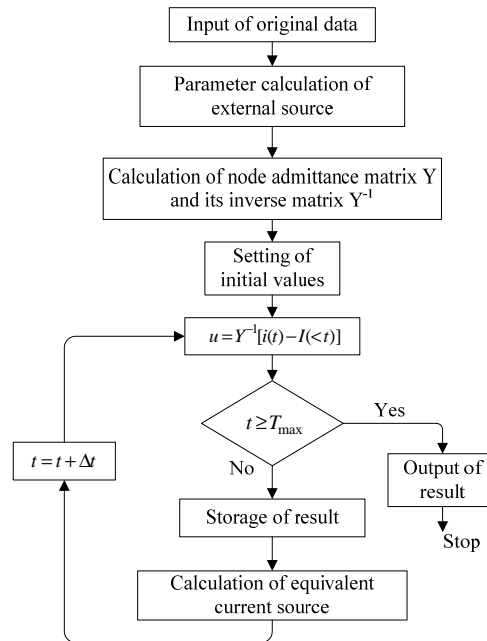


Fig.5. Flow chart of calculation function

A basic feature of GIS transient program (GISTP) developed is graphical interface. The graphical components are designed according to electric main wiring diagram for primary system and are automatically converted to transient simulation model, which keeps unanimous with usage of field operating personnel to the greatest extent. The software provides convenient graphical operations like “zoom”, “rotate”, “copy”, “delete”, “move”, etc. User may draw and modify the wiring diagram easily through the clicking and movement of the mouse. In the process of drawing, input, browsing and modification of the element parameters are finished through Clicking the element, and then ejecting the dialogue box. After parameter settings are finished, network equation is automatically generated and calculated. Main equipment of GIS for transient calculation is shown in table 1, and main interface of the software is shown in Fig.6.

### 3.1. Definition of Graphic Elements

In the graphic system of power system, power system components have some same basic events and properties. Because the operation of graphic element is similar with Lable which is on the programming

platform, class MyBtn is derive from class Lable as base class for electric power equipment, all devices or components are instantiation objects of the class MyBtn. This converts abstract components into concrete components, not only makes the program more structured but also improves its readability.

### 3.2. Selection of Graphic Elements

Selection of graphic elements is one of the most important tasks of interactive user interface, because you should select graphic elements at first if you want to edit it. The software selects graphic elements by MouseDown, MouseUp event and so on in C#. In the graphic system, graphic element itself has a specific area, selection of the element can be judged by the area where the coordinate of mouse click is located, and then the element selected is represented by change the color of graphic element.

### 3.3. Connection Between Graphic Elements

First and foremost, connectable area of the element should be judged by the quantity of element port and the rotation angle of element before connecting elements. Every element has left and right node objects and left and right clicking properties. While connecting elements, clicking actions are recorded, and the element objects clicked are added to the property of a new node object, then the property values of new node object are assigned to corresponding node objects, the same value means that the corresponding nodes are connected. Network topology is obtained after connection [8].

### 3.4. Realization of Calculation

Calculation mainly includes the establishment of the nodal admittance matrix and the column vectors of current

TABLE I. DRAWING DESIGN FOR MAIN EQUIPMENT OF GIS

Element	Drawing	Equivalent model
Line		Lossless transmission line
Closed circuit breaker		
Closed disconnector		
Opened circuit breaker		Capacitance
Power Transformer		Capacitance
Potential transformer		Capacitance
Control switch		Neglect
Current transformer, Opened disconnector	Neglect	

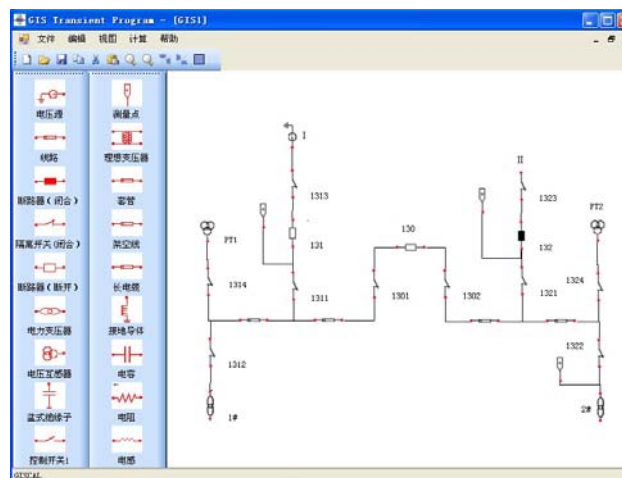


Fig.6. Main interface

source. While the software is starting calculation, the node admittance matrix is obtained by judging the connection of the network. Then, corresponding current source and its parameters are set up according to component type. Finally, all of the above values are substituted into network equation to calculate.

## 4. System Features

GIS transient program is mainly used to calculate VFTO of GIS, and its features are as follows:

- 1) The element models are in conformity with electric main wiring diagram for primary system, and vivid graphic display is easier for field operating personnel to use.
- 2) The calculation process of the software is so simple that network topology and calculation results are obtained and saved automatically on condition that you input element parameters, and you can check the results through document and waveform.
- 3) The software adopts object oriented technology, and all components are instantiation objects of the base class. Therefore, new elements are conveniently added to the system, which offers a better scalability and adaptability.

## 5. Experimental Verification by EMTP

The network shown in figure 3 is calculated by making use of GISTP and international electro-magnetic transient program (EMTP) [3], and the two results of the calculation are same from the waveform (Fig.7), which verifies the accuracy of the software.



(a) Result of GISTP

(b) Result of EMTP

Fig.7. Waveform

## 6. Conclusion

In conclusion, on the basis of object oriented program (OOP) technology a method for developing transient calculation software for Gas Insulated Substation (GIS) is presented in this paper. The software has a friendly human-machine interface and powerful function of graphic editing based on Visual Studio 2008, and OOT. The user may establish the equipment model according to electric main wiring diagram for primary system instead of mastering transient modeling theory of electrical equipment, and the graphical components are automatically converted to transient simulation model. Practice proves that the software developed by this method can combine effectively graphic editing and calculation function, which satisfies the demand of field operating personnel to the greatest extent and has high practicability and broad application prospect.

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