Research on agile generation method of electromagnetic transient simulation model based on multiple information sources

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Abstract. Based on electromechanical transient simulation data, an electromagnetic transient simulation model can be quickly generated through a computer program. However, electromechanical transient data are not sufficient to describe completely the corresponding electromagnetic transient simulation model. In view of this, the paper proposes an electromagnetic transient simulation model generation method that integrates multiple information sources. First, the data characteristics of electromechanical transient simulation software PSD-BPA and electromagnetic transient simulation software PSCAD/EMTDC are introduced. Then, considering the difference between electromechanical transient and electromagnetic transient model data, a method to quickly generate PSCAD/EMTDC simulation data is established. This method is based on the electromechanical transient simulation data, and takes into account those information which is not available in the electromechanical transient data but needed in the electromagnetic transient in the conversion process, so that the converted model is more detailed and accurate. Finally, this method is used to model and analyse an actual fault. The simulation results show that the method proposed in the paper is effective and credible.

1. Introduction

The electromagnetic transient process of power system refers to the electric field and magnetic field as well as the corresponding voltage and current changes in each component of the system[1]. Electromagnetic transient simulation is an activity that uses numerical calculation methods to simulate the electromagnetic transient process, aiming to finely model the target system and obtain detailed time-domain waveforms of various transient responses. It is a tool to understand and master the transient state of the power system in planning, design, operation and scientific research[2-3].

Simulation modelling is the most important part of electromagnetic transient simulation. The rationality and accuracy of the model have a decisive influence on the simulation results. At present, there are two methods for establishing models for electromagnetic transient simulation. One relies on human operation and it is mainly provided by simulation software. The approach is similar to building blocks in the place, where various models are combined and connected. The other is to use the data translation program to automatically generate the model based on the power flow or electromechanical transient simulation data [4-13].

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Comparing the above two methods, it is obvious that the second method has higher work efficiency and lower error probability. By using this method, the simulation analysts can effectively solve the complex model tasks, and spend more time and energy on those problems that need to be analysed and solved. Therefore this method has attracted the extensive concern of engineering and academic circles. Electranix Corporation has developed the commercial software E-TRAN, which is used to convert the data of the electromechanical transient simulation software PSS/E into the model data of the electromagnetic transient simulation software PSCAD/EMTDC[6]. However, the current conversion method focuses on the using the electromechanical transient simulation data as the only source of information. In order to build a model with more detailed data and higher accuracy, it is necessary to combine more information sources to generate electromagnetic transient models.

2. Model generation method

Based on electromechanical transient simulation software PSD-BPA and electromagnetic transient simulation software PSCAD/EMTDC, a model conversion method, which incorporates electromechanical transient simulation data and other information sources, is discussed in the section.

2.1. Brief description of PSD-BPA and PSCAD

2.1.1. Data format of PSD-BPA. The electromechanical transient simulation data in PSD-BPA includes two parts: power flow data and dynamic data, which are stored as GBK-encoded text files with the file suffixes "dat" and "swi". The power flow data contains power flow control statements, annotation information and model parameters. The dynamic data has a similar format.

The power flow control statement is divided into three levels:

- The text line which begins with the character "(" and ends with ")" represents level 1 control statement,
- The text line which starts with the character "/" and ends with "\" represents level 2 control statement,
- The text line which starts with the character "">" and ends with "<" represents level 3 control statement.

It is noted that the comment information is indicated by a text line beginning with ".".

Model data is also called a data card, which is represented by a line of text beginning with a specific character or character string. For example, the text line beginning with "BS", "B", "L", and "T" respectively represent slack node card, AC node card, transmission line card and two-winding transformer card.

All types of data cards have a fixed string format. Each data card contains various fields that describe the corresponding model. Take the slack node "BS" card as an example, its format is shown in Table 1.

| Field name       | column position |
|------------------|-----------------|
| Card type        | 1-2             |
| Modified code    | 3               |
| Owner            | 4-6             |
| Bus Name1        | 7-14            |
| Bus Base1(kV)    | 15-18           |
| Zone             | 19-20           |
|                  |                  |
| Arranged voltage value | 58-61        |
| Angle value      | 62-65           |

2.1.2. Data format of PSCAD/EMTDC. The simulation data of PSCAD is saved in Extensible Markup Language (XML) format in a file with pscx suffix.
The file contains simulation settings, model display settings, simulation model data and so on. Taking a simulation model of a two-winding transformer as an example, the data fragment is shown in Figure 2.2. It can be seen that the simulation model mainly contains two kinds of information, one is the parameter used for electromagnetic transient simulation calculation, and the other is used to display the layout parameters of the model on a canvas.

![Figure 1. Two-winding transformer simulation data fragment in PSCAD/EMTDC](image)

2.2. Model generation strategy
At present, most methods only use an information source (electromechanical transient simulation data) to generate electromagnetic transient simulation models. However, electromagnetic transient simulation requires more model parameters than electromechanical transient simulation, which is reflected in the following types of components:

① Transformer model, PSCAD needs to input winding connection type and neutral grounding information, but it is not required in PSD-BPA;

② Transmission line model, the lumped parameter model used in PSD-BPA cannot accurately simulate the electromagnetic transient response process of long-distance transmission lines. Moreover, although the PSD-BPA line model contains length field, the length information is not involved in the calculation of electromechanical transient simulation, so most PSD-BPA line data may not contain length information. In the absence of line length information, it can only be generated as a lumped parameter model in PSCAD/EMTDC, which may reduce the accuracy of the simulation model;

③ Generator model, the saturation characteristics of a machine in PSD-BPA is represented as a math function which is fitted according to its no-load characteristic curve, so it is required to enter the parameters of the function; while in PSCAD/EMTDC, it is required to directly input multiple pairs of data points on the no-load characteristic curve of the machine, which are composed of magnetic field current and terminal voltage. Obviously, instead of transforming the model, it is better to use the raw no-load characteristic curve of the machine directly.

Based on the above discussion, it is more feasible to use multiple information sources to quickly generate electromagnetic transient simulation models. Other sources of information contain the following:

① Data in the power grid equipment management system, it includes information such as transformer winding connection type and transmission line length;

② Energy management system (EMS) data, it includes information such as transformer neutral grounding mode;

③ Generator factory data and generator control system test reports, it usually contains information such as generator no-load characteristics.
The model generation strategy which integrates multiple information sources is shown in Figure 2. It includes the following three steps:

Step 1: The electromechanical transient simulation data is converted into an intermediate data file that is easy to expand, read and write;

Step 2: The missing parameters of the electromagnetic transient model in the intermediate data file are filled by the other information sources;

Step 3: The intermediate data file is used to generate model parameter information in the electromagnetic transient simulation model.

Figure 2. Structure flow chart of model generation method.

As it can be seen from Figure 2, the intermediate data file is equivalent to an intermediate representation between the electromechanical transient model and the electromagnetic transient model. In specific implementation in this paper, the intermediate representation adopts the Excel file format, and various component data are stored in different workbooks. These workbooks contain not only the data in PSD-BPA, but also data from other information sources.

Take a two-winding transformer shown in Table 2 as an example. The corresponding workbook includes the values of the other fields except the card type of PSD-BPA, as well as the transformer winding wiring method and the neutral grounding method.

Table 2. Two-winding transformer intermediate data file format.

| Bus Name1 | Bus Base1(kV) | ... | Winding 1# type | Winding 2# type | Winding 1# neutral point grounding | Winding 2# neutral point grounding |
|-----------|---------------|-----|----------------|----------------|-----------------------------------|-----------------------------------|
| GEN1      | 15            | ... | Δ              | Y              | No                                | Yes                               |

3. Numerical example

3.1. Case description

In order to verify the effectiveness of the proposed method, it is used to generate a simulation model of a regional power grid, and a simulation study is carried out.

For ease of description, the regional power grid is referred to simply as grid N. Network N has a 220kV substation (hereinafter referred to as station A) and several 110kV and 35kV substations. It is connected to the main network through a 220kV line (hereinafter referred to as line AB).

In the power grid, a 150MV hydropower plant (hereinafter referred to as plant C), which supply the power through a 220kV line (hereinafter referred to as AP line), is the main power source. In addition, there are also some small hydropower units in the network. The 220kV wiring diagram of N network is shown in Figure 3.
After the fault trip on line AB, the network formed an isolated network, and failed to maintain stable operation.

On the power supply side, Plant C maintains an output of 73 MW for about 7.55 s (During this period, the unit frequency rose to 57 Hz). After that, the unit output suddenly dropped to about 25 MW. Plant C continued to carry out frequency and voltage regulation, but due to large voltage fluctuations in the isolated grid and high unit temperature, 16 minutes after the AB line tripped, No.2 unit of Plant C was shut down, then 30 minutes after the AB line tripped, No.1 unit of Plant C also tripped due to overtemperature of bearing bush.

On the power grid side, about 1 minute after line AB tripping, all the five wheel low frequency load shedding devices located in the 110 kV and 35 kV substations operated. As a result, the load was reduced by 85 MW. Followed by the action of the load shedding devices and tripping of No.1 and No.2 units of Plant C, the load dropped to about 5 MW which was supplied by small hydropower units. After other units in plant C also tripped, the 220 kV bus voltage magnitudes of station A and plant C exceeded 250 kV. Due to the excessive voltage, the AP line and the main transformers in station A were tripped successively.

During the fault process, it is necessary to pay attention to the phenomenon of low frequency load shedding and over-voltage. Qualitative analysis shows that the fast closing of guide vane for No.2 unit in plant C may be the main reason for the action of low frequency load shedding. The cause of the overvoltage are as follows.

After the operation of low frequency load shedding, there were very light load in the isolated grid and the active power flow transmitted by the line was close to zero. At the same time, the lines in the isolated network generated a certain charging power through the capacitance to the ground. Before No.1 unit of plant C was tripped, it was in the phase-advance operation condition, so the charging power generated by the lines in the isolated network was balanced. After it was tripped, there is excess reactive power in the isolated network, so the overvoltage occurred.

### 3.2 Simulation verification

A computer program is developed and used to agilely generate the corresponding simulation model. Then, the model is used to verify the correctness of the above-mentioned qualitative analysis.

The simulation waveform of the isolated grid frequency is shown in Figure 4. It is obvious that the guide vane of No.2 unit in plant C shut down too fast, which can trigger the operation of low-frequency load-shedding. It shows that the simulation results verify the rationality of the qualitative analysis conclusion. In addition, the simulated response of the isolated grid frequency, including the maximum value reached by the frequency rise and the action value of low-frequency load shedding, are basically consistent with the actual data.
Figure 4. Isolated grid frequency simulation waveform.

Next, the cause of overvoltage is simulated and analysis. Figure 5 and Figure 6 are respectively the fault recording and simulation waveform of 220kV bus voltage in plant C. By comparing the two figures, it can be seen that the simulated waveform is basically consistent with the actual fault recording, the bus voltage has risen from 231kV before the trip to about 254kV.

4. Conclusion

This paper proposes a fast generation method for power system electromagnetic transient simulation model which utilizes multiple information sources. This method considers that the electromechanical transient simulation data is not enough to describe the electromagnetic transient simulation model. Therefore, when carrying out the model conversion, not only the electromechanical transient simulation data is used, but also other information sources are integrated. This makes the generated electromagnetic transient model more detailed and accurate. The method proposed in the paper can help simulation staff to build simulation models conveniently and quickly.

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