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Simulation Modeling for Electrical Switching System of Hydropower Station

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Abstract

This paper proposes a simulation modeling method for the electrical switching system of hydropower station, which is a sub-topic for Hydropower Station Simulation Training System. The graphics model of commonly used electrical switch equipment is developed with a certain software [1]. As vast and different types of Hydropower station circuit breakers and associated grounding switches, and each specific action of the switch process is not same, so the modular modeling method is described to solve the problem. According to the role and status in power plant, electrical switch system is divided into several sub modules, among which a number of small modules are sorted in. In each sub module, a common model is developed. Besides, the application method that the network topology analysis algorithm used in electrical switching system simulation logic judgment is introduced. With the 'connecting line fusion' technique, logic function expression member information table is automatically generated, thereby enhancing the suitability for the electrical switch simulation model. The methods mentioned above assure the real-time, typicality and flexibility in simulation, and have been successfully used in the development of a large hydropower station simulator.

***Keywords**: electrical switching simulation, hydropower station, topology analysis algorithm, object-oriented*

1. Introduction

Simulation training system for hydropower station is a modern digital simulation training system, which simulates the production progress of hydropower station by using the computer technology and provides actual training environments (central control room of hydropower station). Electrical switching simulation models are a part of and a link within simulation training system. Whether normal operations, abnormal operations, emergency handling, equipment "Put in/out" operations, starting and stopping process, or protective action process all involve corresponding operations and actions in the system. Therefore, the establishment of a reliable, real-time and friendly electrical switching system simulation model is an indispensable part of simulation training system.

So far, the hydroelectric station simulator or simulation system that has been put into operation and practical use can be numbered. Reference [2] introduced several key techniques for the development of engineering equipment virtual training system. The majority is single-unit-oriented machine-electricity conversion process simulation, and the whole station-oriented electrical switching system simulation is surprisingly few. Due to the limitation of computer and multimedia technology, early simulation training software isn't user friendly, resulted from the lack of graphical effects of its result display. With the development of computer and multimedia technology, hydropower station simulation software has the interface with the same style of Windows, featuring friendly interface, powerful function, convenient and quick modeling, and visual output.

This paper introduces the development process and achievements of electrical switching system simulation for hydroelectric station, including graphical simulation modeling, functional general simulation modeling, implication of power network topology analysis algorithm, and the development of simulation training system, etc.

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2. Visualization Development

Graphical simulation modeling is building their own simulation model according to the needs of the simulation objects. And it reflects the demand of visualization, which is one of the vital parts of visualization simulation [3]. Reference [4] introduced several visualization development techniques in TCS Simulation which provided a unique thought of design.

2.1. The Development of Graphic Elements of Switches

The software 'Visual Graph' includes the following three basic elements: Words, Lines, and Shapes. With scripting language inside the elements, basic graphics above are able to demonstrate strong vitality. With scripting language packaged into these equipment components, developers do not have to consider the specific implementation process, and regard them as a complete object directly.

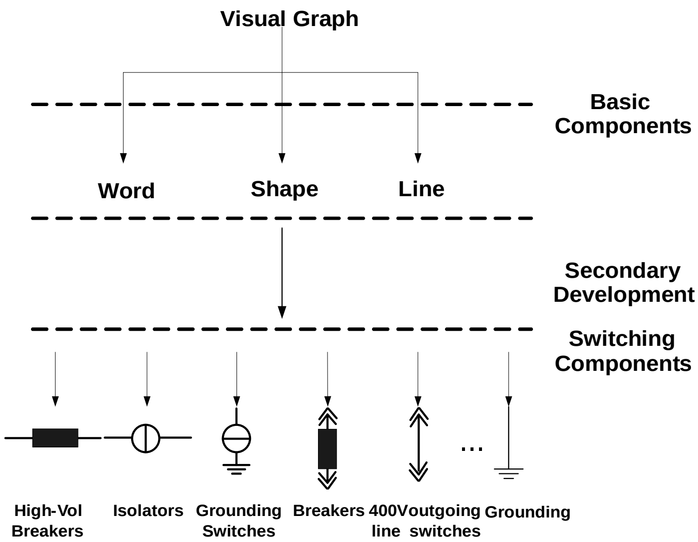

Figure 1. Schematic Diagram of the Development of Graphic Elements

2.2. The Development of Graphics Library

The number of switches in all monitor screens is large, besides, the control handles, closing buttons, and signal indicator lights on local control cabinets are various. For example, there are hundreds of breakers in switching station, GCB (Generator Circuit Breaker), and breakers for house-supply in the whole system. Among breakers' local handles, control handles can be divided into 'near/remote control' handles, oil pump handles, and 'close/open' buttons. For the convenience of the development of RMON (Remote Network Monitoring) [5] screenshots and local control cabinets, it's of great requirement to establish a common library of graphical elements. To realize the graphical elements versatility, there is need to conduct a comprehensive analysis of the properties of all switching devices, then merge the components as many as we can, and realize the component library versatility finally.

3. Generalization of Simulation Modeling

The operation simulation process can be divided into the following steps: firstly, simulation Man-Computer operation interface issues a correct order to LCU (Local Control Units); secondly, LCU devices conduct logic blocking judgment according to the program, that is, 'The Five Anti Rules of Electrical System [6, 7]', if legal, the order will be transmit to switching cabinet, otherwise, error information will be displayed on the alarming window pop-up from the interface; then, program will conduct a fault check, the switch will act with no fault in it, otherwise, failure phenomenon will occur, and feedback detailed failure information to man-computer interface. The overall action process of switching is as Figure 2 and Figure 3.

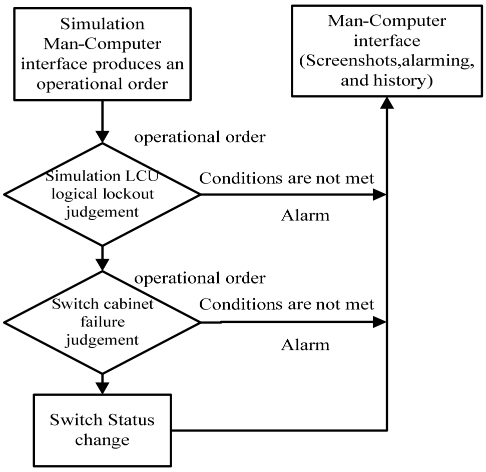

Figure 2. The Procedure of Switching Operation

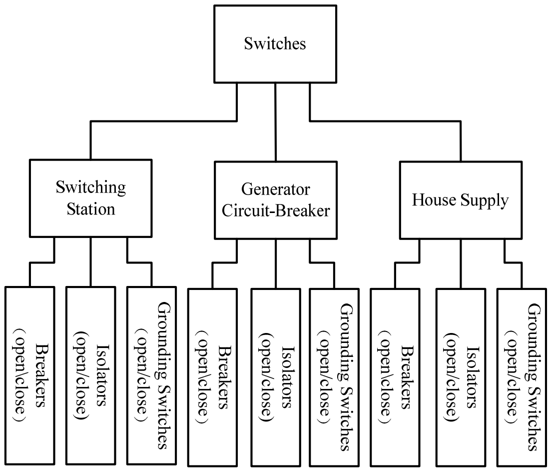

Figure 3. Switch Hierarchical Classification Diagram

Due to the fact that breakers and associated switches in the entire hydropower station differ from types and each switch has its own process, which is not quite the same as the others, from the programming perspective, all the switches must be divided into the following hierarchic and classification. If necessary, it can be further subdivided each subclass.

For the representative description, setting remote breaker's synchronized closing as an example. Firstly, given the fact that a breaker in switching station has three types of operation modes: synchronized closing, no-voltage auto-closing, and opening; and there can be several users which send a same order or a coupe of ones to a same breaker at the same time. So, it's of great importance to realize the lockout of the certain functions during the closing period. Then, it's necessary to judge the control mode during the breaker's action according to the layering control method of hydropower electrical switching system. Finally, the synchronized closing procedure of the breakers in switching station is illustrated as Figure 4.

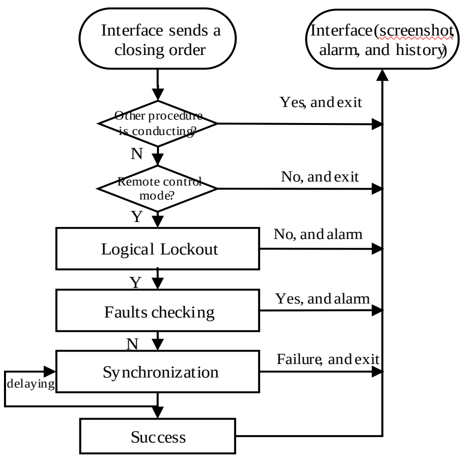

Figure 4. Breakers' Synchronized Closing Procedure

4. The Realization of Topological Analysis Algorithm in Power Network

Topology analysis is the progress of the investigation on the geometric texture and link characteristics that between equipment components of power network by using graph theory, with its purpose to reflect the connected relation and corresponding state of equipment components. A computer-convenient mathematical model can be realized according to the real-time conditions and dynamic states of connected component [8, 9]. The topology analysis just reflects the physical connected relation of components and has no concern with electrical specifications of them.

Topology analysis in this paper method is based on the technology of connecting line fusion and switch combination. Lead in non-electrical equipment component connecting line as the auxiliary tool, which can automatically generate connection in the progress. Then according to the wiring structure of actual hydropower station, a wiring diagram can be built by using the graphics elements.

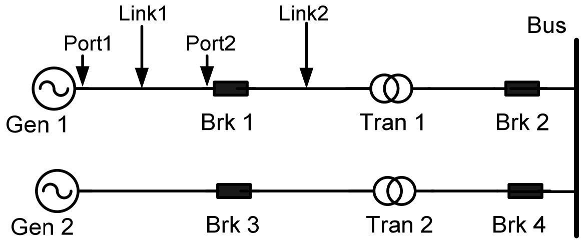

Figure 5. Electrical Network Topological Graph

As shown in the Figure 5, Generator 1 connects with one port of Breaker 1 through connecting line while the other port of Breaker 1 connects with one port of Transformer 1, which connects with Bus 1 via connecting line and Breaker 2. The connection progress of Generator 2 is similar. From the above analysis, a connecting line makes two ports of different equipment elements linked. It is convenient to describe the network topology structure and pave the way for the realization of topological analysis algorithm.

Topology analysis algorithm based on the connecting line technology needs to number all the ports in sequence, as shown in the Figure 6.

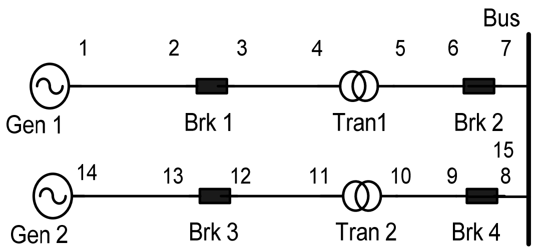

Figure 6. Diagram of Original Equipment Components Ports' Number

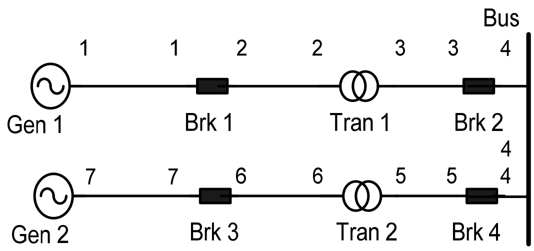

Figure 7. Diagram of Ports' Number after Merging the Connecting Lines

Traverse all the connecting lines and integrate all the ports' number meanwhile according to the following methods.

1) Supposing that the ports on both sides of a connecting line which connects devices were X1, X2, if X1=X2, do not handle.

2) If X1 and X2 are not equal, eliminate the larger. The description in programming language is as: if X1 is greater than X2, then X1=X2 (assignment), if not, X2=X1 (assignment).

3) Traverse all equipment ports, if X1 or X2 is greater than the larger one in procedure 2), the figure of equipment number minus 1, as shown in Figure 7.

After merging the connecting line through above steps, the connection condition can be conveniently described by programming language:

Generator[1]. Node1：= Breaker[1]. Node1
Transformer2[1]. Node1：= Breaker[1]. Node2
Transformer2[1]. Node2：= Breaker[2]. Node1
Bus [1].Node1：= Breaker[2].Node2
Bus [1].Node1：= Breaker[4].Node2
Transformer2[2].Node1：= Breaker[4].Node1
Transformer2[2].Node2：= Breaker[3].Node2
Generator[2].Node1：= Breaker[3].Node1

Take ˝Generator[1].Node1：= Breaker[1].Node1˝as an example, this expression is interpreted as the port between Generator 1 generator and Breaker 1 equals Node 1.

The network after the combination of connecting line can accurately reflect the physical connection conditions in electrical network, graphical connection relations between devices successfully converted to a description in computer programming language. The electrical switching system simulation model for hydropower station can use it to form a switching logic function information table an information table of the members' constitution in expression of logic function.

5. Application Example

The designs of visualization development, generalized models and network topological analysis algorithm have been applied for switching simulation training system for a certain large hydropower station, which has 9 generators and 6 outgoing lines. Each generator connects main transformer with generator circuit breaker, and then connects switching station through high-voltage cable. 500kV station belong 5 series of breakers using 4/3 main connection and connect to CSPG with 6 outgoing lines. The control procedures of all switches in the plant can be divided into 7 categories: 10KV house-supply control procedure, 400V house-supply control procedure, house-supply outgoing lines control procedure, auxiliary control procedure, public control procedure, generator control procedure and switching station control procedure.

Having the aid of joint debugging which concludes electrical models, auxiliary models, relay protection models, and fault models in the overall hydropower station simulation training system, it finally build up a complete large hydropower station simulation training system software.

One server, two trainer stations and thirty trainee stations are deployed in this simulation system with Ethernet network. Solaris OS is installed in the server. Windows XP OS are installed in the working stations. Huge data transmission for switching simulation utilizes memory-sharing. Data Concept model is built by E-R approach and corresponding relational database is realized by ORACLE DBMS. The tables can be divided into 3 categories: electric element; protection and parameter. The software on the working station is developed by Delphi with excellent human-machine interface. Switching model software is developed by object-oriented language based on designed class diagrams and sequence diagrams.

6. Conclusion

The paper designs visualization development, generalized model and network topology analysis algorithm of switching simulation training system for hydropower station in detail, according to its characteristics and switching simulation system's standards and requirements. Principles of the design include: authenticity of simulation and friendly man-computer operation interface; reliability and generalization of model code; good integrate with other modules in simulation training system [10]. In the future, the following aspects should be perfected: further improvement of the switching models with stronger self-adaptability, which can be adapted to different hydropower stations; further completeness of contents in electrical switching models, containing research of the secondary return circuit of switches.

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