MULTIFUNCTIONAL DISPATCHER TRAINING SYSTEM FOR SUBSTATION

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ABSTRACT

Using the dispatcher training system(DTS) to train the dispatchers is an effective way to improve their operations. This paper presents the structure and important modules of DTS for substation. The 3D technology is introduced to make the simulation more comprehensive and vivid, so, the system gets more complicated, the data exchange mechanism is introduced in detail. Besides the main module, some other function modules are also introduced to make the system more flexible and convenient. This system can be well used in the other substation of the same type. The design idea can also be used for other training system for reference.

INTRODUCTION

Substations have been playing an important role in the power grid. They're closely related to the safety and reliability of power system. With the expansion of power grid and the development of automation technology, the monitoring system of substation gets more and more complicated. Dispatchers must be trained to be familiar with all kinds of icons and operations. Through effective training, they can also be skilled and experienced when they face emergencies [1].

Since the power system is very special, those general training, which will impact the power supply reliability, could not be conducted in the real system. Constructing a simulation system provides the dispatchers a very good environment to practise their operations [2].

The normal running status and the fault status are simulated in the system. Dispatchers can do all kinds of operations in the simulation system. DTS will also react to these operations. Besides normal operations, the fault handling ability is also very important. Some specific faults are simulated in DTS. They can be triggered by the instructor, thus, dispatchers can be well trained to handle with these different kinds of fault. DTS has greatly improved the ability of dispatchers. It has been one of the most important means to guarantee the safety of power system [3].

ARCHITECTURE OF DTS

The traditional training for dispatchers was mostly conducted through documents, charts, two-dimensional interfaces and other changeless modus. These modus are always abstractive for dispatchers to learn. The changeless interfaces are not able to display the comprehensive running status of substation. Multimedia video teaching is able to provide specific and vivid scenes and details about the operations in substation. However, there is almost no interaction between dispatchers and the video. They could not get practical experience. As a result, the effect of training is not really good.

Structure

In order to solve these problems, the new training system must be visualized and interactive. DTS can fully meet these requirements. The monitoring system could be totally rebuilt in DTS, dispatchers can take operations just like in the real system. Besides the simulation of the primary system, the protection system is also built in DTS. What's more, the 3D technology is introduced into the construction of DTS. A virtual reality system is built to shown the scenes of the substation. The inspection and fault handling can be carried out in the virtual system. With the help of the new training system, dispatchers can be trained comprehensively and effectively [4].

No matter the monitoring system or the visual reality system, the interfaces displayed to dispatches are based on the simulation of power system. Different modules work together to support the DTS. The structure of DTS is shown in Fig.1.

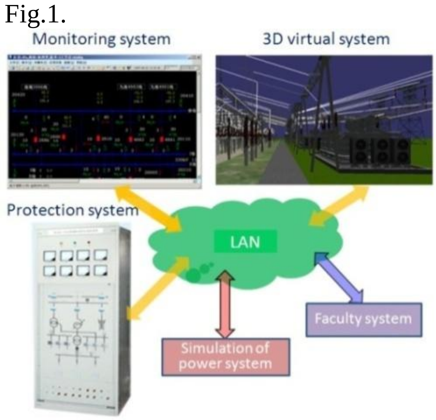

Figure.1: Structure of training system

The whole system is composed of three big function modules [5], simulation module, faculty module and the dispatcher module.

Simulation module

The simulation module consists of the simulation of power system and the protection system. It lays foundation for the whole training system. The power grid topology and the model of protection are built in this module. Besides, the data information is also stored in this module. The value of current, voltage, frequency and other state properties can well reflect the condition of the substation. Once there is a fault, they will reflect the fault characteristics. The structure of simulation module is represented in figure 2.

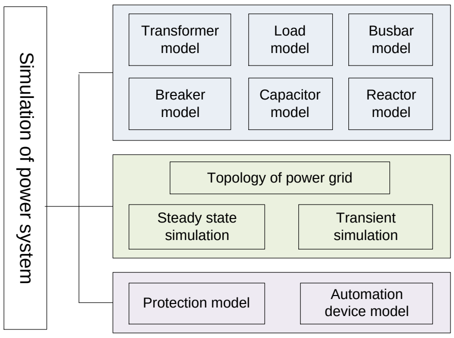

Figure.2: Structure of simulation module

The protection system simulates some important protection in the substation. Such as the protection for transformer, busbar, line, breaker and so on. These protections are simply classified as shown in figure 3. The principles of the protection are simulated, while the setting values are listed in an independent window for the dispatcher to modify. Once the instructor sets a fault in the system, the relay should act correctly to isolate the fault. The operating cabinets are displayed in particular interface. Dispatcher can also make manual operations through this interface.

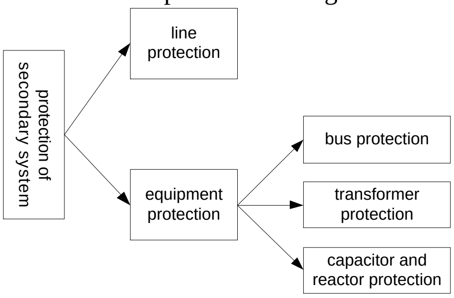

Figure.3: Classification of Protection

Faculty module

The faculty module is responsible for the controlling of the whole training. It's an instructor station, which is synchronized with the dispatcher module. In this module, instructor can set the running condition of the simulation system, such as the output of generator, the load, the operation mode and so on. They can also monitor and control the training process, for example, developing the training plan, determining the time to start, recording the operation of dispatcher. During the training, instructor can also set various kinds of fault randomly, thus, the dispatchers can be trained more experienced to face accidents. In a word, the faculty module enables the instructor to participate in the training from beginning to the end, which makes the training more flexible and effective.

Dispatcher module

The dispatcher module consists of monitoring system and the 3D virtual system. All the operations and inspection can be simulated in this module.

The monitoring system is responsible for the background operations. The electrical information can be monitored and the instructions can be sent out through this system. The grid of the substation, the power flow, the voltage and current of important equipment, the status of breakers and other electrical information are displayed here. With the information, dispatcher can well know the running conditions of the substation. When fault occurs, dispatcher can also sent out instructions immediately to isolate the fault and ensure the safety of power system.

The 3D virtual system provides a virtual sense of the substation, which makes the training more vivid and complete. Dispatcher is able to walk in this system. They can also make some operations. The electrical equipment and some important operating cabinets, meters and switches are displayed here. The 3D system is synchronized with the monitoring system. However, some special performance, such as the transformer oil leakage, the breakdown of some connection device, they can only be reflected through the physical model of equipment. These events should be treated separately in the 3D system.

DATA EXCHANGE

Since the faculty system, monitoring system and the 3D system reflect the substation at the same time. The association among them and the data exchange mechanism are very important.

Association

The instructions sent from the faculty system, such as cutting the load and changing the output of generator, they will all affect the status of the simulation system. Besides, the operations done by the dispatcher through both the monitoring system and the 3D system will also affect the running of the system. Any effective operation or the action of relay will affect the performance of the system. The current, voltage, power flow, status of breakers, and the signal shown in the cabinets will change. Meanwhile, these changes should be synchronously displayed in the faculty system, the monitoring system and the 3D system. Since the simulation system is the core of DTS, these different terminals are all connected to it. This kind of association can well promise the synchronization of the whole system. The association among them is shown in figure 4.

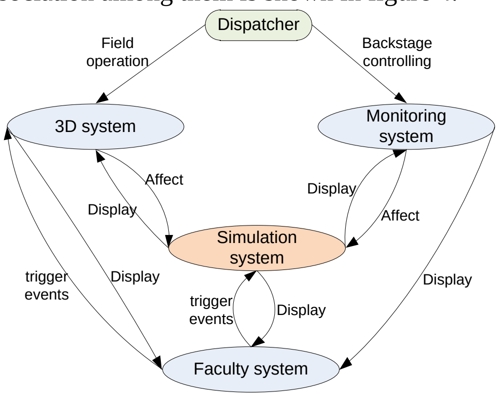

Figure.4: Association among different modules of DTS

Model

The association among different modules are accomplished through the unified database in simulation system. The mathematic models are very important. There're various kinds of electrical components in substation. Different classes can be established for different kinds of equipment. For different class, the properties are different. For example, the class for load should contain the properties such as current, voltage, and power flow, while the class for breaker should reflect the status of breaker and the number of times it act. The information revealed to the dispatcher and instructor is extracted from the database based on these models [6].

However, without the description of the connection among these components, they're independent, and the simulation of the system can't be conducted. The topology of the system is described through nodes and junctions. For each component, besides the physical properties, it has properties for node. Node reflects the connections of this component. For example, a load component has only one node since it can only be connected from one point. But a busbar component has several nodes, because it can be connected with many loads and other components. A breaker component has two nodes, it connects with two components. Once each component has the property for node, the topology of the substation can be described by junctions and the status of breakers. If two components are connected, their nodes will form a junction, otherwise, they are not connected directly. Meanwhile, most of the component are connected through breaker, if the breaker is closed, they are connected, otherwise, they are independent.

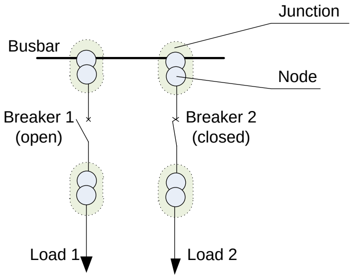

Figure.5: Diagram of the connection for components

Realization

With the models of all kinds of electrical components and the description of network topology, the database can be built and the calculation of power flow can be well conducted [7]. The information shown in faculty system and monitoring system can be easily obtained from the database.

However, the 3D system is different. The electrical information in 3D system must be the same with monitoring system. But, most of the information in 3D system is shown through meters, which are not digital. This means the digital data must be transferred to the value that can be read by meters. For example, the current flow through a branch is 20A, and the range of the meter in 3D system is 100A. The current should be expressed as 0.2 for the meter to recognize. It means that the data in the main database can't be directly applied for 3D system. What's more, 3D system is much more expected to provide a vivid scene of the substation to dispatcher. The physical models of equipment and circumstance are very important. These models also have many different physical conditions, which can't be obtained from the main database. According to the special demands of 3D system, a separate database for 3D system must be built, and a synchronization program should be introduced to accomplish the data exchange. The new database should not only contain the physical information of the equipment in substation but also be synchronize with the main database to ensure the unity of the whole system. The data exchange mechanism is shown in figure 6.

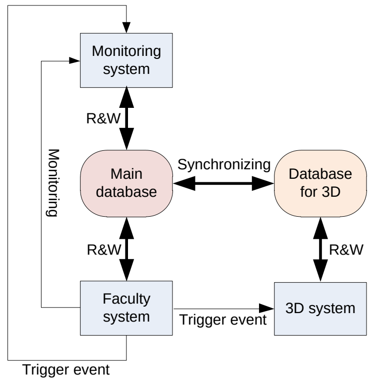

Figure.6: Data exchange mechanism of DTS

INTELLIGENT MODULE

Besides the required modules analysed above, there're other expansion packages, which provide useful functions for the training. These packages are relatively independent. They can be flexibly configured as needed.

Anti-maloperation system

The anti-maloperation system can help the dispatcher to avoid some faulty operations. When the instruction is send out, it will be checked according to the status of system. If the instruction is incompatible with the operation rules, this anti-maloperation system will give a warning and the instruction will not be carried out. The wiring in substation varies if the operation mode changes. The logical judgment should follow with strict formula. A library should be built to describe all kinds of operation rules.

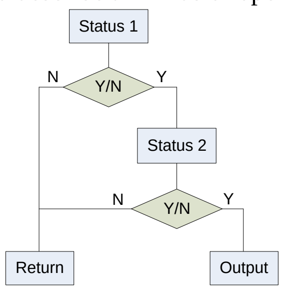

Figure.7: Schematic of anti-maloperation system

Taking the simple operation, closing a breaker, for example, status 1 and status 2 refer to the status of the two isolating switches on each side of the breaker. The breaker can only be closed when both of the switches are closed. Otherwise, the operation will be locked. The operation rules can be described by this kind of diagram as shown in figure 7..

Automatic scheduling

For dispatchers in substation, it's very important for them to execute every operation correctly when they change the running status of equipment or change the operation mode. An operation schedule is made out to guide them. The traditional way is to list the schedule manually. However, it takes too long time and it's easily to make mistakes. In order to solve this problem, the computer-assisted technology is widely used in substation, which is automatic scheduling. This function module is also developed in DTS for better training. The flow chart of the implementation is shown in figure 8.

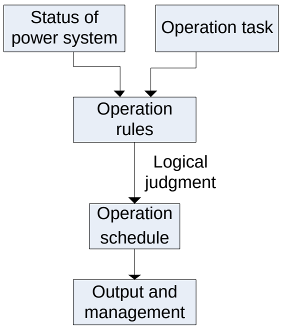

Figure.8: Flow chart of automatic scheduling

The automatic scheduling system can provide an operation schedule for the operation task automatically. Once the system got the task, the related information is collected. The information will then be checked according to the operation rules. After that, the operation schedule which conforms to the operation rules is created. It will be output to a certain window for dispatcher to carry out. The typical operation schedule can also be stored for the future use.

Other useful function module can be introduced into DTS. For example, the intelligent evaluation system can help the instructor to find out the mistakes made by dispatcher during the training, which is more effective. The teaching plan edition system ensures the instructor to make the training plan in advance. Certain event can be triggered at certain time, which is more convenient.

CONCLUSIONS

DTS is a multifunctional system, which is very effective for the training of dispatchers. As a simulation system, it should be comprehensive and realistic. However, some other requirements for this huge system are also very important. Firstly, it should be generic, which means it can be conveniently used for the similar substation. Then, it should be extensible. There should be enough program interfaces, thus, new function modules can be easily introduced to the original system for the later extensions. Besides, the maintainability of the system must be good. If the topology of the system changes, it should work well without the change of the original source program.

REFERENCES

[1] Montstream, M.J., Ross, H.B., Jr., 1995, "An online dispatcher training simulator function for real-time analysis and training", *IEEE TRANS on Power Systems*, vol.10, 1798-1804.

[2] Miller, G.L., Storey, A.B., Vadari, S.V., Brewer, K.L. 1993, "Experiences using the dispatcher training simulator as a training tool", *IEEE TRANS on Power Systems*, vol. 8, 1126-1132.

[3] HAN Nian-hang, WANG Su, ZHANG Hui-gang, 2007, "Maintainers oriented substation automation technique training system", *Automation of Electric Power Systems*, vol. 31, 88-90.

[4] ZHANG Bing-da, ZHANG Pu, 2008, "Application of virtools in substation simulator", *High Voltage Engineering*, vol.34, 338-341.

[5] Shin, B.C.G., Gibson, P.F., Wangen, B.R., Perez, L.A, 2011 "Wide-area DTS implementation in the Western Electricity Coordinating Council", *Power and Energy Society General Meeting, IEEE*, 1-8.

[6] Chaumes, P., Antoine, J.-P., Bihain, A., Stubbe, M., 2000, "Advanced dispatcher training simulator" *Computer Applications in Power, IEEE*, vol.13, 25-30.

[7] Jiaomin Liu, Yi Sun, Haibo Li, 2008, "The Research of Real-Time Database Technique Used in Power System Dispatcher Training Simulator", 3rd International Conference on Innovative Computing Information and Control, 9-12.