A COMPREHENSIVE SIMULATION TRAINING SYSTEM FOR THE REGIONAL POWER NETWORK

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INTRODUCTION

The necessity to build a comprehensive simulation training system for the regional power network is put forward in this paper on the basis of an analysis on the development situation of simulation training system for the power network and the current problems. Combining with the development of Nanjing Electric Power Company’s comprehensive simulation training system, the technical considerations for realizing this system, main features and practical applications of this system are introduced in this paper.

1. OVERVIEW

1.1. Current situation on training of regional power production and power network operators

Operation management of a regional power network consists of three sections: dispatching center, transformer substation centralized control center, and transformer substations. The three sections are inseparable each from other in running of a regional power network; they each has its own duty, and coordinates with other; a problem with any link will impact safe, steady, and economical running of the regional power network.

Along with rapid development of the national economy, a large number of primary and secondary equipment have been put into operation, and various regional power networks has constantly expanded in their scales, too. In this case, lack of operators with comprehensive knowledge and rich experience is a widespread phenomenon in many electric power companies, especially in the transformer substation centralized control centers newly-built in the last years. Statistic data show that a quite large part of accidents in regional power networks originate from human factors, are consequences of the defects and abnormal phenomena failed timely and rapidly to be treated by the operation persons concerned. In order to ensure an electric power system safely and reliably runs in a high quality and economical condition always, abundant knowledge, experiences, and capability enough to deal with different running problems, including those in normal, emergent, abnormal and accident conditions are essential requirements for the dispatching and operating personnel in the electric power system. For these reasons, it is very significant to enhance building a simulation training system used for operators has important significance for improving their operative level.

1.2. Situation and shortages of the current simulation training system

The simulation systems used for training of regional power network operators mainly include two modes: one is the simulation training system for the power network dispatchers; another is a single substation simulation training system for the operators in a transformer substation. Both the systems are independent each of other, and have the following shortages:

(1) Lack of completeness. These existing simulation training systems cannot meet the requirements for training on-duty operators of the centralized control centers in simultaneous monitoring multilevel tension substations because of short of the simulation of transformer substation centralized control center in them. Moreover, both the systems are independent each of other, not an integrated system, and so cannot be used for combined training. Therefore, they do not reflect mutual effect between a regional power network, its transformer substation centralized control center, and transformer substations, and complete process of production running of the regional power network.

(2) Lack of consistency and authenticity. In the production running of a regional power network, the three sections including the dispatching center, the transformer substation centralized control center, and transformer substations form an inseparable organic integral, treatment of all normal, abnormal, and accident conditions in the regional power network is jointly completed by operators in the three sections through mutual coordination. The existing simulation training systems do not completely take the model of whole the regional power network into account, lack the consistency with practical production process of the regional power network, in other words, without well authenticity, and so cannot be used for comprehensive training of dispatchers of the power network and operators of the centralized control centers.

(3) Incomplete and faulty simulation. The existing simulation training systems are incomplete and faulty in their simulation, specially in simulation of the primary equipment such as transformers, switches, mutual inductors, lightning arresters, bus bar, lines, and the likes, which are basically not concerned in, cannot meet the requirements of operators for visually learning in-field equipment.

1.3. Developing trend of the simulation training system for operators of power networks

The following points may be summarized from the developing trend of the simulation training system for regional power networks:

(1) The three sections including the dispatching center, the transformer substation centralized control center, and transformer substations together form an inseparable organic integral, but a simple isolated system, therefore, an
integrated simulation training system for regional power networks combined simulation of a regional power network, simulation of its transformer substation centralized control system (SCADA), and simulation of transformer substations together is a developing trend in future.

(2) There are many types of transformer substation centralized control system (SCADA), which have their individual own characteristics, and thus which necessarily coexist on the long-term basis. The transformer substation centralized control system should adapt simulation of multiple control systems (SCADA), and has a stronger adaptability.

(3) In consideration of the fact that Intranet of the electric power companies has reached a practicable standard, the Intranet hardware platform-based simulation training system and the multimedia tele-training and tele-education system will have a wide developed prospect.

(4) The multimedia technology and the reality-virtualized technology is one of final targets of the computer science development, especially for faults and abnormal conditions of many primary equipment, the simulation training system can fully bring multimedia, 3-D graphic technology, and reality-virtualized technology into play for many faults of the primary equipment.

2. REALIZATION OF THE SYSTEM

2.1. Design target of the system

Dispatchers of a regional power network, operators of the transformer substation centralized control center, and operators of transformer substations jointly take on the heavy responsibility of safe and economical running of the power network. Under the united command of the dispatchers of the regional power network, they coordinate each other, jointly complete the task to operate normally and deal with abnormal events and accidents in the regional power network. Such a working mode requires a set of comprehensive simulation training system for the regional power network, to playback completely the production process of the regional power network, simulate vividly and fully various phenomena and change of parameters, and reflect the relationship in which the power network, the transformer substation centralized control center, and transformer substations act and influence each on other. In the simulation training using the system, trained dispatchers of the power network, operators of the transformer substation centralized control center, and operators of transformer substations will receive a combined training for the personnel at the three levels at their individual human-computer interaction interfaces. In such a mode, in the training, the dispatchers take in action on the site and necessary information on the equipment, and deal with various simulated events with a sense of reality; the trainees of transformer substations practice how to execute dispatching command, bringing up a system concept and overall point of view in practical operation running. They will become qualified operation persons soon because their capacity to deal with accident and coordinate and harmonize is enhanced in the training. Furthermore, for the theoretical knowledge, a set of content-plenty multimedia tele-education software is required to develop for providing tele-education and examination functions, and realizing “Dispersed training and centralized examination”.

2.2. Monolithic construction of the system

In full consideration of current production running mode (regional dispatching — centralized control station — transformer substations) of regional power networks in this country, we design such as monolithic structure as shown in Figure 1 for the system, to utilize the original dispatching simulation training system of Nanjing Electric Power Company and reduce repeated investment.

![Figure 1 Comprehensive simulation training system](image)

2.3. Simulated scope

To let operators of the power network be familiar with and master the practical structure and running mode of Nanjing regional power network, a simulation model, which part of power network completely corresponds to practical structure, and parameters of Nanjing regional power network, and main connections of transformers, is set, except for proper simplification of user feed lines. The simulated scope includes all 220kV and 500kV wire frames, important 110kV, 35kV lines and necessary power apparatuses, such as transformers, fail-safe devices, relay protection devices, and the likes, in the network, the external networks are subject to equivalent treatment.

2.4. Software function

(1) Simulation of the power network. The part to simulate the power network may simulate all the changed situation including simulation of system, such as steady power flow, simulation of frequency, simulation relay protection, simulation of a system failure, containing calculation of a short circuit, simulation of fail-safe devices, and data acquisition in the power network after an operation or accident occurs in the power network.

(2) Simulation of SCADA system at the dispatching terminal. There are actual SCADA functions of the control center on the desktop of each dispatcher trainee, and its operational interface is the same as that on the actual
dispatching desk. The realizable SCADA functions include:

- Data acquisition and updating
- Override and stand-off monitoring
- Alarm treatment
- Human-computer interface

(3) Simulation of transformer substation centralized control center. Simulation of the transformer substation centralized control center includes simulation of apparatuses such as topping set, channel cabinet, and the likes, and simulation of SCADA system, taking RD-800, OPEN-2000, WNT-8000 as prototype of simulation, and allows addition of new type of SCADA system as request.

(4) Simulation of transformer substation

- Primary equipment.
- Secondary equipment.
- Relay protection and automatic devices.
- Virtual patrol of Primary equipment in a transformer substation.
- Simulation of comprehensive automation system of a transformer includes simulation of equipment and simulation of human computer interface functions.

3. TECHNICAL FEATURE OF THE SYSTEM

3.1. Integrated design of simulation of the power network, simulation of the transformer substation centralized control center, and simulation of transformer substations

In order to realize exactly synchronization and interaction of tele-communication, tele-metering, tele-control, tele-adjustment, and in-field operation of a transformer substation, as well as a series of simulation including those of network faults, equipment accidents, relay protection and automation device at the dispatching station, centralized control station, and transformer substations, to realize integration of simulation of the power network, simulation of the transformer substation centralized control center, and simulation of transformer substations, and to reflect correctly mutual action and effect between the power network, the transformer substation centralized control system, and the transformers, and finally to realize full simulation of the production process of the regional power network, the following techniques are adopted in this system:

(1) Open and distributed simulation software support platform. So-called simulation training support system has good expandability and flexibility, can meet different needs of regional power network of the different scales for comprehensive simulation training systems. The system has a reasonable open, configurable, and expandable constitution.

(2) Complete, normal, and scientific communication protocol for the comprehensive simulation system. A complete, normal, and scientific set of communication protocol for the comprehensive simulation system is worked out for building of the information exchange platform for simulation of dispatching a power network, simulation of centralized control station, and simulation of transformer substation.

3.2. Adoption of real-time system data section and truth protective constant value

In order to get more truth results on change and frequency of power flow distribution of the whole simulation training system, ensure correctness and reliability of simulated relay protection and automation device action, the following techniques are adopted:

(1) Adoption of real-time system data section. The comprehensive simulation training system may be kept in accord with the actual system by regularly maintaining the power network model. By connection with dispatching automation real-time system Open2000, real-time data section of the electric power system obtained is taken as the initial condition for the training, which enhances sense of reality of both simulation of the power network, simulation of centralized control station, and simulation of transformer substation.

(2) All-system simulation constant value judging technique is adopted in relay protection. All-system simulation constant value judging technique is adopted in relay protection, and the combined simulation system and DMIS system share relay protection data, which ensuring exactness of the protection data and fault simulation. The technique can correctly calculate the short circuit current values of various faults by analyzing the faults in simulation and simulate action of relay protection in various complex conditions.

3.3. Transformer substation virtual device technology and physical apparatus-oriented module technology

The virtual instrument generating and managing technology are adopted in the system for transformer substation. Various primary and secondary apparatuses in a transformer substation separately generate their own virtual apparatuses based on their individual physical characteristics. The module technology may transform these virtual apparatus utility software into independent and reusable nodules, from which a complete transformer substation simulation utilization system may be assembled. In such a way, a system gets simpler in its structure, easier to develop, and is well open and expandable.

3.4. Web-based tele-training technology

Some technologies including Active-X, Multimedia, Knowledge Stream, and Plug-in Card are adopted in the tele-training software of simulation training system, and they form a open, distributed, user-oriented, and self-improvable multimedia tele-training software platform with a three-layer B/S structure together.
4. MAIN FUNCTIONS OF THE SYSTEM

4.1. Training of production running personnel and management personnel concerned

(1) Training of running skill. Training and testing of running personnel’s basic running capacity, enable them to be familiar with the structure, running mode, and power flow of the power network, master basic operation and dispatching procedure, be familiar with running of the real-time monitoring system (SCADA), operation-bill generating system, and other utility software.

(2) Analysis and settlement of accidents. Training running personnel of the power network learn how to find accident, judge and treat fault according to the simulated power network environment, and analyze the accident after the training ends. The training playbacks the whole process of occurrence and treatment of the accident, analyzes correctness of each step of operation, and give correct tip.

(3) Normal and special patrol training of primary equipment in transformer substations. 3D playback and virtual operation of transformer substation apparatuses is realized with the help of 3D Interactive roam patrol system of transformer substations, giving the trainees a true and vivid impression. This is helpful to them in being familiar with the production field, and better combining theoretical knowledge with practical experience.

(4) Power network running concept training of office administrative staff. Office administrative staff may know current situation, running mode, operation procedure, and running feature of the power network.

4.2. Combined anti-accident manoeuvre

It is useful to further perfection of various accident contingency preschemes, and consequently enhancement of the capacity to copy with various accidents to carry out regularly purpose-clear all-networks anti-accident manoeuvre on the basis of deep investigation of characteristics of the regional power network, and accident contingency preschemes aiming at weak links. A common accident or a complicated accident set in the simulation power network, if occurs, will lead to interlocking actions of relay protection and change of power flow in the power network, and displaying of the warning prompt of the override apparatus. The experience of dealing with accidents in the power network may be summarized by investigating these facts above, and accordingly a reasonable accident contingency prescheme also may be worked out. Besides, actual accident data may be used to playback the accidents, and analyze cause of the accidents for seeking anti-accident countermeasures and optimize the running mode. It may be realized by the above-said efforts to have analysis before an event, and feedback after the event, and safe running capacity of the power network will be surely improved.

4.3. Auxiliary analysis on power network running management

The data after evaluation of the actual power network state may be used to analyze reasonability of the current power network running mode in its safety, and to study and work out special power network running mode including change of the mode, adjustment of unit overhaul mode, future power flow distribution of the power network, and festival and long-term examine and repair. In addition to the above-said, the simulation system may be used to verify the setting value of relay protection, and work out a reasonable countermeasure and put them on records.

4.4. Multimedia tele-training

The multimedia tele-training system is based on Web’s B/S structure, and used on Internet and Intranet. It is used for tele-education and tele-training, and may meet demand of regional dispatchers, transformer substation centralized control center running personnel, and transformer substation running personnel for learning, training, and advanced studying. This eliminates the conflict with them between work and study at root, not only realizing the purpose of “Dispersed training and centralized examination”, but also greatly remitting the pressure of education and training on the electric power company.

4.5. Utility effect of the system

The system can meet demand of regional power network of different scales for simulation training system because the system is strongly configurable. It may be configured into not only a regional power network comprehensive simulation training system with the mode of “Regional power network dispatching center - transformer substation centralized control center - transformer substation”, but also an independent regional power network dispatcher simulation training system and a transformer substation centralized control simulation training system including transformer substation simulation training system, realizes training in different running environments (OPEN-2000, RD 800, and WNT-8000) in multiple transformer substation centralized control systems, and accordingly is warmly received by on-duty operators.

The system normally becomes a basis for 35–500kV transformer substation on-duty personnel in the whole province in 2003. Since 4th November 2002, 338 110kV on-duty operators, 446 220kV on-duty operators, and 311 500kV on-duty operators and 31 dispatchers have received the training.

Brief introduction to authors

Jiao Jin, female, born in 1954, senior engineer served for Nanjing Electric Power Company, engaged in administrative work of education, training, and science and technology of the electric power system.

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