An Operation and Maintenance Training Platform for Distribution Terminal Unit

Zhiyuan Pan1*, Hongwei Li1, Jing Wang1, Ganrong Peng2, Guanghong Li1

1State Grid of China Technology College, Jinan, Shandong, 250000, China
2State Grid Jinan Power Supply Company, Jinan, Shandong, 250000, China
*Corresponding author’s e-mail: panzhiyuan@sgtc.sgcc.com.cn

Abstract. Distribution terminal unit is an important part of distribution automation. The application and maintenance of distribution terminal unit is directly related to the operation effect of distribution automation. In order to improve the technical level of power company maintenance personnel, the distribution terminal unit operation and maintenance training platform is designed. It is also beneficial to understand the principle of distribution terminal unit, the action process of distribution automation, and master the daily operation and maintenance operation of distribution terminal unit. According to the actual faults in the distribution automation, the platform realizes the primary fault simulation of the distribution network and the secondary fault simulation of the distribution terminal unit. Then the maintenance personnel will carry out operation and maintenance operation to remove the fault. Its application improves the level of operation and maintenance operators.

1. Introduction
As an important part of distribution automation system, intelligent distribution automation terminal (DTU) is the core part of realizing intelligent perception of distribution network. It provides switch on/off position, voltage, current and other distribution network operation parameters for distribution automation master station [1]. At the same time, it carries out the commands issued by the master station, regulates and controls all kinds of primary power distribution devices, and realizes the functions of fault location, fault isolation and fast recovery of power supply in non fault areas. In order to ensure the normal operation of distribution automation system, a large number of operation and maintenance personnel are required to carry out debugging, operation and maintenance and troubleshooting. How to improve the professional level of operation and maintenance to meet the needs of smart distribution grid has become a common problem faced by power supply companies of all [2].

To meet the requirements of distribution terminal operation and maintenance wiring, it is necessary to build a simulation training platform to realize the fault simulation of primary devices of distribution grid and secondary equipment fault simulation of distribution automation. Now, power system simulation is an important means to study the dynamic behavior of power grid, ensure the stability of power grid and optimize the operation. It can be divided into physical simulation and digital simulation. The physical simulation method is based on the similarity principle and uses the actual physical equipment after equivalent conversion. Physical simulation generally has high simulation credibility, but it is difficult to simulate the operation of large-scale power grid due to its huge investment, difficult parameter change and limited simulation scale. Digital simulation makes full use
of modern numerical calculation methods and computer processing ability, and has a series of advantages such as low investment, easy reconstruction and large-scale simulation. However, the results of digital simulation depend heavily on the mathematical model and simulation algorithm of the equipment, and the accuracy of the model will directly affect the accuracy and credibility of the results. The hybrid simulation technology combining digital simulation and physical simulation can take into account the advantages of the above two methods, and has been widely used in current simulation systems. The fault simulation of primary devices in distribution grid needs to combine physical simulation and digital simulation. The system fault inspection and maintenance of the electrical secondary circuit is the key content of the daily work of the power department. The operation and maintenance personnel should strengthen the research on the work and structural characteristics of the electrical secondary circuit, clarify the main causes of various faults, and take reasonable preventive measures. The secondary circuit mainly includes control circuit, signal circuit, measuring circuit, regulating circuit, relay protection and automatic device circuit, operating power supply system. In the past, no matter the theory course or the practical operation course, only pictures and words can be used to explain to the trainees. The on-the-spot trainees will have less mobile phones, less opportunities for independent operation, slow improvement of trainees’ skills and poor training effect. At home and abroad, the setting and simulation of power distribution terminal fault are relatively few, which need to be deeply studied combined with field equipment.

2. Overall of Training Platform
The goal of the design of DTU operation and maintenance training platform is to use low hardware cost, realize the simulation of the main components of distribution automation system, complete the operation and maintenance training of DTUs, and make the whole set of equipment as small as possible.

2.1. Functional of Training Platform
DTU operation and maintenance training platform needs to simulate the fault of distribution grid and primary device, which can test the functions of distribution terminal and realize the operation of DTU. It includes the following functions:

(1) The simulation of primary equipment fault in distribution network mainly includes line simulation and switch equipment simulation. There are phase to phase short-circuit fault, single phase-to-ground fault and operation after fault, including fault detection and isolation. The simulation of the switchgear includes the opening and closing operation of the switch, and the fault of the switch, such as the energy storage state of the switch equipment and the anti misoperation operation simulation.

(2) The fault simulation of secondary equipment includes remote signaling position error, DTU connection line error, software setting error, secondary circuit wrong wiring, CT short circuit, VT disconnection and other faults.

(3) The training operation can set and remove typical faults on the operation and maintenance training platform.

2.2. Design Of Training Platform Device
The training platform simulates a complete application scenario of distribution automation, including distribution automation master station, communication, DTU, secondary power supply, switch, primary circuit, signal generator, etc., and put them into a standard 19 inch industrial control cabinet, as shown in Figure 1.
In the distribution automation system, the main function of DTU is uploading and command executing between master station and industrial field. To monitor the signal collected by the DTU, the master station is essential. A high performance notebook computer is used to simulate the distribution automation master station. The main applications and modules of the master station system are installed on the laptop to demonstrate the functions of the whole master station system.

Centralized DTU is selected as distribution terminal. A DTU can monitor multiple lines and control multiple switches, so as to realize other functions of distribution automation. The most commonly used optical fiber communication equipment ONU and GPRS communication module are selected for the communication system [3]. Considering that wireless GPRS communication needs to establish a dedicated network operating environment, Wi-Fi module and Bluetooth module are also configured in the equipment to simulate wireless GPRS communication when there is no network operating environment.

To simulate the normal operation state and fault state of 10kV distribution network lines, it is necessary to establish a circuit network which can carry lower voltage level and smaller current. On the premise of sacrificing some simulation similarity, in order to simplify the system complexity, the design scheme ignores line resistance, inductive reactance and capacitance to ground. Using wire, resistance network and relay, the cable, line impedance and switch in the primary line of distribution network are simulated. Simulated circuit breaker needs to simulate the functions of primary switch. It mainly includes three-way fracture of pulse voltage controllable opening and closing, manual isolation fracture and manual grounding knife switch, which has the signal of fracture position and energy storage state signal.
2.3. Trainees
Since the installation and commissioning of distribution terminal training platform was completed in May 2019, it has undertaken more than 20 training tasks and trained more than 150 students. The application of the training platform improves the operation and maintenance student's understanding of distribution automation terminal equipment, and improves the basic theoretical knowledge level and practical technical skills of distribution automation operation and maintenance staff.

3. Simulation of Primary Device and Its Failure
The simulation of primary devices need to simulate the switching operation of distribution lines and switches.

3.1. Simulation of Distribution Lines
The 10kV distribution lines provide power supply for the distribution network. The transmission line uses overhead cable or buried cable. A section switch is set every other distance to realize the regional control of power supply range. In actual operation, single phase-to-ground, phase-to-phase short-circuit, three-phase short-circuit, broken line, lack phase and other faults will occur in distribution network lines. The most common faults are single phase-to-ground fault and phase-to-phase short-circuit fault. The voltage and current on the line will be different from the normal lines when the fault occurs. These characteristics are the important basis for DTU to judge the fault.

To simulate the normal operation state and fault state of 10kV distribution lines, it is necessary to establish a circuit network which can carry low voltage and small current. The main purpose of training platform simulation is to generate fault current, not to analyze the specific characteristics of the fault, so in the simulation, it can be simplified, ignoring line resistance, inductive reactance and capacitance to ground. Resistance network is used to simulate normal load and set various line faults artificially. Using wire, resistance network and relay, simulate the cable, line impedance and switch in the primary line of distribution network. A low-voltage transformer is selected to convert the three-phase 380V AC power into a safe low-three-phase 5V AC. This low voltage is connected to the appropriate node in the analog line. By switching on or off the resistance on the analog line, different current will be generated on the analog line. The load current and fault current can be simulated by this method for the collection of DTU. In order to get more accurate signals and more functions, a relay protection instrument is configured to provide AC voltage and current analog signals for the system, which is used to test the function and performance of distribution terminals. The protection logic can also be tested by state sequence and other methods. To get more accurate signals and more functions, a relay protection testing instrument is configured to provide AC voltage and current analog signals for the platform, which is used to test the function and performance of DTUs. The protection logic can also be tested by state sequence and other methods.

3.2. Simulation of Switch Device
According to the different arc extinguishing media, there are several kinds of 10kV circuit breakers in domestic distribution network, such as oil immersed, vacuum, SF6 and so on. According to the different operation structure, the switch equipment can be divided into electromagnetic switch, spring energy storage switch and permanent magnet switch. The principle of spring energy storage switch is to use the mechanical energy generated by spring expansion and contraction to complete the opening and closing. The advantages of this operating mechanism are that the closing current is small (only for the energy storage motor), the cost is low, and the disadvantage is that the structure is complex. At present, the spring energy storage circuit breaker is widely used. The training platform mainly simulates the circuit breaker with the spring charge mechanism.
4. Simulation of secondary equipment
The common faults of secondary equipment are simulated and trained, including secondary circuit wrong wiring, CT, Pt disconnection, optical fiber disconnection, remote signal point meter dislocation, telemetry point meter dislocation, etc [4-6].

4.1. Simulation of Mainly Faults
Connections error. There are a lot of secondary system wiring in distribution automation, which are used to collect voltage, current and other information. Wrong wiring will lead to wrong information collection. In the actual debugging and installation process, there will be some common faults such as wiring error, wiring looseness, wire disconnection in the middle and so on. This kind of problems are not easy to be found, and they are hidden. When the on-site operation and maintenance personnel are lack of experience, it is very easy to find the problems in time and affect the normal operation of the equipment [7].

| Number | Actual order | Correct order and value | Wrong order and value |
|--------|--------------|-------------------------|----------------------|
| 1      | Position     | Position ■              | Energy deficient □   |
| 2      | Energy deficient | Energy deficient □         | Position ■          |
| 3      | Voltage low  | Voltage low ■            | Voltage low □        |
| 4      | Remote/Local | Remote/Local ■           | Remote/Local □       |

4.2. Secondary Equipment Fault Simulation
The secondary equipment fault simulation device is mainly composed of transfer switch, indicator light, connecting piece, power switch, relay, relay protection and terminal block. The method of logical judgment is simple and reliable. The fault simulation equipment can realize the drawing recognition and wiring of secondary control circuit of medium voltage switchgear. It can explore the control principle and relay protection action. And it can also simulate control operation, secondary circuit fault finding and other practical operation drills for training or assessment. The equipment can realize the fault simulation and setting of four circuit breakers at the same time, which is convenient to simulate the fault between different switches and the disorder fault of inter Bay wiring. The equipment expands the types of faults and the generation mode of faults [8].

5. Conclusions
The operation and maintenance training platform of DTU mainly completes the training operation of intelligent DTUs. Low hardware cost is used to realize the simulation of the main components of distribution automation system. In the training platform, all the components used to simulate the distribution automation master station, communication system, DTUs, power supply, switch, primary circuit and signal generation device are installed into a standard 19 inch industrial control cabinet. And in it a set of simulation micro model of distribution automation system including primary circuit and primary switch is realized. For the majority of distribution automation operation and maintenance personnel to provide practical, targeted and comprehensive, general simulation technology means, improve the training effect.

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