

# Research on Technology for Local Protection Intelligent Maintenance

Zhanglei Zhao<sup>1,\*</sup>, Jianyou Yang<sup>1</sup>, Xialin Dong<sup>2</sup>, Zhenyu Zhou<sup>1</sup> and Bingwei Gao<sup>1</sup>

<sup>1</sup>State Grid Wenzhou Power Supply Company, Wenzhou 325000, China

<sup>2</sup>State Grid Wenzhou Dongtou District Power Supply Company, Wenzhou 325700, China

\*Corresponding author e-mail: 13857765693@163.com

**Abstract.** At present, due to the addition of new secondary equipment such as merging units and intelligent terminals in intelligent substation, the reliability of the system has been reduced, and the trip time of protection has been prolonged. With the promotion and application of local protection devices in the new generation of intelligent substations, The above problem is solved. But the traditional maintenance mode will face new challenges. Aiming at the shortcomings of operation-maintenance mode of the intelligent substations at this stage, considering the characteristics of unified interface standards, small size, replaced easily and protection information transmitted through private network of local protection devices. This paper puts forward a new maintenance mode with centralized device information viewing, intelligent fault diagnosis and status assessment and a new maintenance scheme with factory intelligent debugging + replacing fast maintenance, which will provide reference for the further promotion and application of local protection technology.

## 1. Introduction

The addition of intelligent terminal, merging unit and other process layer devices in intelligent substations at this stage cause the increasing of intermediate transmission and conversion links of relay protection system, resulting in the decrease of speed of protection actions, which will affect the stability of the system finally. Simultaneously, with the addition of public equipment such as merging unit, intelligent terminal and switches, the total number of equipment in intelligent substations has increased greatly, and the failure rate of such equipment is higher ( more than twice of the failure rate of protection in conventional substations), which will further increase the daily equipment maintenance workload. Aiming at the problems existing in intelligent substations at this stage, State Grid Corporation began to investigate, research and test for local protection since 2016. Canceling the intermediate links such as merge unit and intelligent terminal, using local protection scheme of which the relay protection device is installed close to the primary equipment and the local cable can jump point to point. The scheme has become an effective way to solve problems existing in the above mentioned intelligent substations.

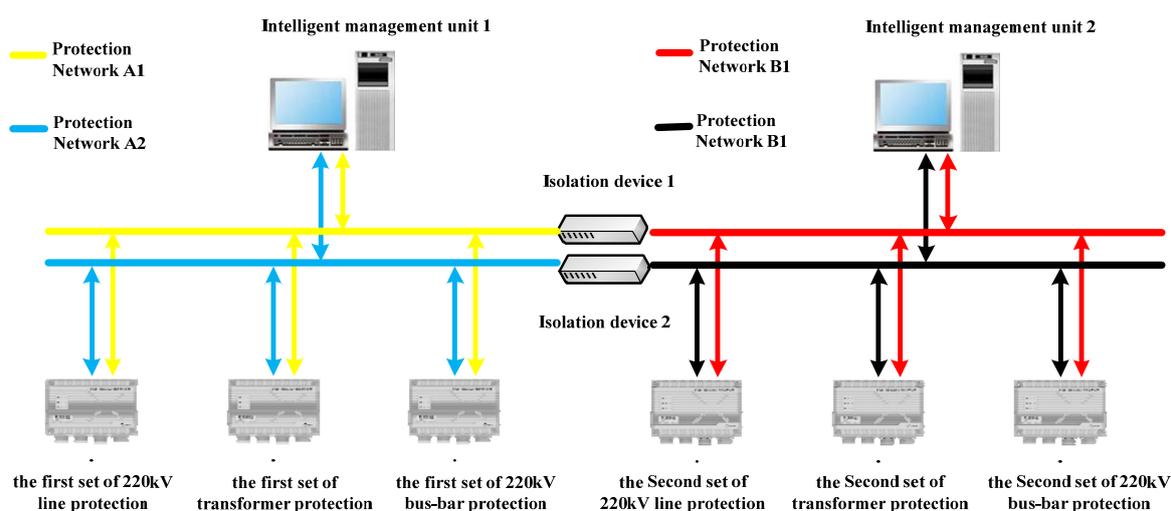
Currently, online test of the 220kV line protection installed locally without protection has completed under all kinds of severe meteorological conditions. 220kV and 500kV full-type local protection (including main transformer protection, bus differential protection, line protection, breaker



protection) has been put into trial operation online. 110kV local protection has entered the actual operation stage. With the promotion of local protection in the new generation of intelligent substations, it is necessary to design a new maintenance scheme for the local secondary equipment. Aiming at the shortcomings of the operation-maintenance scheme of intelligent substations at this stage and combining with the characteristics of local protection devices, this paper introduces a intelligent operation-maintenance scheme for local protection.

## 2. Conventional operation and maintenance and its shortcomings

Relay protection is the important barrier of grid security. The failure of relay protection will lead to extension of accident of power system fault, affecting safety and stability of power system. Therefore, the effective way to ensure the reliable operation of relay protection equipment is state monitoring and regular maintenance of relay protection device and its secondary circuit in the substation. Due to the large number of process level equipment installed outdoor used in intelligent substations, low level of outdoor protection, and high thermal power of numerical, and the secondary circuit associated with relay protection is complex, which will make it difficult to effectively monitor its reliability. At present, Power Company's operation and maintenance staffs need to periodically inspect and record the equipment plug-in components' temperature and air conditioning system installed outdoor. While repair personnel can't accurately assess the status of reliability of the relay protection equipment and its secondary circuit, usually using preventive maintenance. The maintenance test of the relay protection device and its secondary circuit shall be carried out according to the inspection procedures for relay protection, in order to ensure that the device components are undamaged, the function is normal, the circuit wiring and setting values are correct, and the healthy operation level of relay protection is improved. However, the number of 110kV and above substations in the State Grid Corporation of China has reached 17,000 since 2018, while the number of related operation and maintenance personnel maintains around 10,000 for years. The workload of equipment maintenance and regular overhauling is heavy, and it is still rising trends year by year. Facing the expanding scale of power grid, the configuration of relay protection personnel can't satisfy the need of equipment maintenance and overhauling in some companies which have a large number of maintenance sites. Heavy workload and high work intensity has also become outstanding issues during the process of relay protection equipment maintenance in traditional mode.



**Figure 1.** The structural diagram of 220kV full-type local protection.

### 3. Intelligent operation-maintenance program for local protection

According to the characteristics of unified interface standards, small size, replaced easily and protection information transmitted through private network of local protection devices, We can implement a new maintenance mode with centralized device information viewing, intelligent fault diagnosis and status assessment When the equipment needs daily equipment inspection and maintenance. Similarly, we use a new maintenance scheme with factory intelligent debugging + replacing fast maintenance, when the device requires routine testing and emergency failure.

#### 3.1. Intelligent maintenance mode

The local protection device has no LCD screen. The related protection information has been sent to the intelligent management unit through the protection private network. Because all the information is integrated in one place, the efficiency of inspecting equipment can be greatly improved. During the daily inspection of the equipment, unit, we can complete to examine equipment abnormality information (including hardware failures, channel failures, board temperature alarms) in the management. Moreover, we can check device setting value, sample value and differential current. In addition to the above basic monitoring functions for device information, the intelligent management unit can also implement online fault diagnosis and status assessment for local protection.

(1) According to the device's hardware-level alarm information, monitoring information, other inspection information, and the statistical trends of monitoring information, we can evaluate the operating status of the device and give fault early warning;

(2) According to the temperature of each plate sent by the device, it can realize the query for temperature history data and the dynamic display of data change curve. By setting the temperature warning value, the over-limit alarm of the device temperature can be achieved;

(3) It can realize over-limit alarm and historical data query of the voltage, and dynamic display of change curve.

(4) It can realize the port light intensity of sending/ receiving by device process level protection private network and device ring network The light intensity alarm of fiber cross-link channel and historical data query can be achieved;

(5) It can realize over-limit alarm of differential current and function of historical data query;

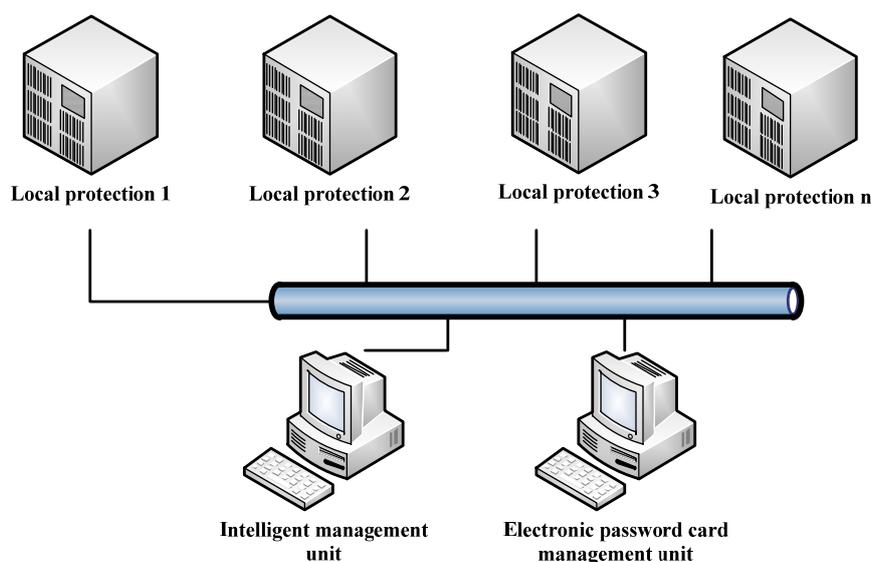
(6) The date of primary and secondary equipment by the same source can be compared. Inconsistency monitoring of the dual switch signal and dual AD input information can be achieved; through the monitoring of the above information, the accuracy of alarm information points, alarm levels, and alarm modes can be determined correctly. Alarm and visual displays can be performed according to different classification.

(7) According to the intermediate node output information of the protection, combined with other information in the station, intelligent diagnosis analysis of the hidden failure in protection can be performed. Data evaluation and processing advice can be given.

In summary, the intelligent equipment fault diagnosis and status evaluation system platform is constructed by local protection and intelligent management unit. It can fully obtain equipment operating data and historical data. Through real-time comparison of the analogous, switch signal, and other homologous data, and combined with the statistical analysis results of the equipment historical data, a comprehensive evaluation report of the local protection device can be periodically generated. It provides data support for the establishment of equipment inspection and maintenance plans. In addition, when the device has any problem, we can analyze and judge quickly, and locate accurately the fault point to the board level.

During the operation of local protection, we are able to modify the device fixed value, switch the fixed value zone, one-button backup and download, put in or out of soft pressure plate, and do other control operations by the intelligent management unit. Therefore, it is necessary to check the related operations against misoperation by the intelligent management unit. It consists of device identity verification and autonomous error detection prevention.

The structural diagram of identity verification system is shown in FIG. 2. The radio frequency card (or UKey) is dedicated to each operating worker. The identification code of the device to be operated can be written into it through the electronic password card management unit. When the control operation is performed on the intelligent management unit, the identity information stored in the system and the identity information read in the radio frequency card will be automatically compared. The operation can be allowed to proceed if they are unanimous. Otherwise, the operation is immediately alerted and the operation is prohibited. We can double verify the operation and maintenance personnel's operation authority and the consistency of the operated equipment by the identity verification system, which can effectively reduce the possibility of misoperation.



**Figure 2.** The structural diagram of Identity verification system.

The active integrated anti-error detection is divided according to the function of the intelligent management unit. Only the anti-misoperation judgment of the relevant secondary device operation is performed. The relevant judgment logic is as follows:

(1) The judgment of whether a system is running

When we put out the functional pressure plate of transformer low voltage side slave, we should confirm that the circuit breaker of the transformer low-voltage side is in the open position and that the low-side current sampling value is 0. It can avoid the misoperation possibility of putting the pressure plate, if the system of related side is running. Others, busbar protection disconnects the soft pressure plate of accepting goose or line protection disconnects the soft pressure plate of sending goose, we need to judge the state of the related system.

(2) Judgment on the prevention of misspecification for special functions

Doing the drive test without power cut, the active integrated anti-error detection system can automatically check the real-time load current to prevent the drive test in heavy load from affecting the stability of the system. At the same time, it can check the important alarm signals such as control circuit and atresia reclosure. After confirming that there is no abnormality, the operation of drive test can be performed.

### 3.2. Replacing maintenance scheme

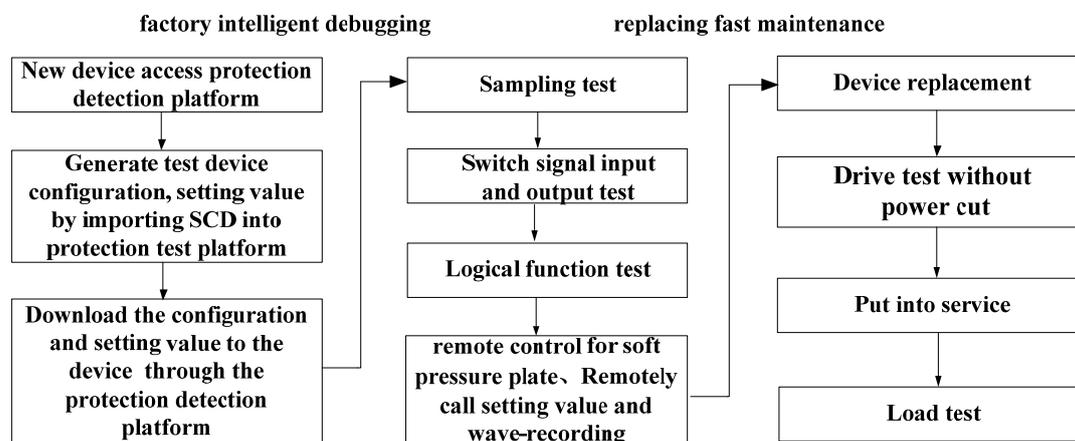
When local protection break down during operation, the following maintenance mode mainly would be adopted, which can be divided into the following steps (as shown in Figure 3),

Step 1, complete one-key configuration and testing of the device in advance at the debugging and maintenance center.

Step 2, replace whole machine after arriving at the scene.

Step 3, drive without power cut after the device is put into operation.

Step 4, finally, complete the on-load test automatically.



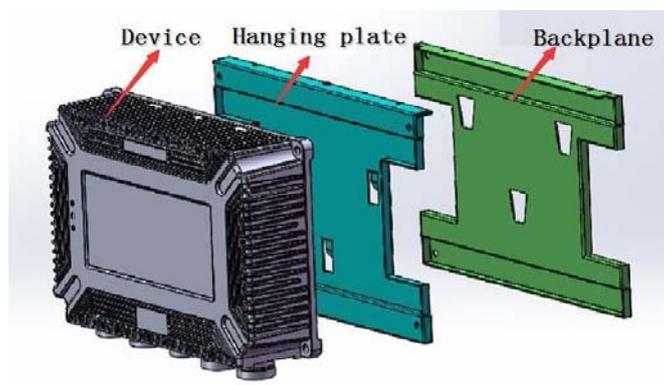
**Figure 3.** The flow chart of maintenance for Local protection.

#### (1) One-key configuration and testing

Local protection factory debugging and maintenance center is equipped with protection inspection platform, which has local protection standard interface, free wiring and use easily and conveniently. With function of AC sampling, remote communication, protection, communication, automatically test hour function, and download device configuration file one-key. The inspection scheme of the test platform is flexible. A single device can be tested, which multiple devices can also be tested in parallel. The test process is highly automated, tests of relevant function can be one-key completed and generate test reports automatically. It can greatly improve the testing efficiency of the local protection device.

#### (2) Replace whole machine after arriving at the scene.

The protection device is installed on the side wall of local terminal box, connecting terminal array and device through air plug. First, disconnect the air plug before replacing. Air plug is designed standardly and it can enable rapid replacement of equipment between different manufacturers in special situations. When disassembling air plug, for its special mechanical structure design, the current circuit automatically can be shorted from head to tail, which provide security for the replacement process. At the same time, its appearance adopts different ribbons and fool proof design of fault-tolerant key technologies, which can effectively reduce the risk of "mis-wiring" for repair personnel. "Hang first and screw later" steps are used when the device is installed. Show as in figure 4. 1. Firstly fasten the device to the hanging plate by screws. 2. Secondly, fix the hanging plate on the back plate through buckle. 3. Finally, fix the hanging plate and the back plate by screws. The above installation method is convenient to operate and can meet the needs of field installation and overhauling individually replace job requirements.



**Figure 4.** The structural diagram of hanging part for local protection device.

### (3) Drive without power cut

After device replacement is completed and put into operation on site, to verify the correctness of outgoing loops of the device, drive test without power can be performed. Enter the interface of drive without power of the corresponding device in the intelligent management unit, under the premise of not affecting the original logic and functions of the protection device, the device sends a short trip command according to the phase. In combination with the reclosing function of the device, the interval power supply can be quickly recovered. In case of the following conditions, the device will lock the function of drive without power cut automatically. 1. The protection device encounters any alarms such as PT disconnection, CT disconnection, and channel abnormality, 2. Protection starts due to system disturbance, 3. Continuous transmission is operating, while the interval is less than 1 minute. 4. The reclosing choose "disabled" mode Or the reclosing is in discharged state.

### (4) Load test

For those protection device replaced with power cut which only undergoes current-voltage tests of its primary equipment and for those protection device have to be replaced without power cut for eliminating deficiency emergency. It is necessary to verify the correctness of the voltage and current loops through automatically load test performed by the intelligent management unit. The test module can display the three-phase voltage and current amplitude and phase for the required intervals, displaying in the form of schematic diagram of the relationship between power and angle, judging the correctness of the CT, PT transformation ratio, CT phase sequence and polarity through the internal program, and the test conclusion is given.

### (5) Actual replacement case

Communication failure occurred in a line protection. Equipment maintenance diagnostic system in intelligent management unit judge that the device CPU module is damaged. The measure we take is the whole machine replacement. The entire process and time consuming are shown in Table 1. The protection in original intelligent station or conventional station has any problem. We usually use replacement solutions for plug-in. After the processing is completed, we need to conduct on-site debugging according to the type of plug-in that we replaced, such as pass current and voltage test, protection logic test, drive test, load test, etc. Its overall time-consuming is about 3 hours. Now we use the new maintenance scheme with factory intelligent debugging + replacing fast maintenance. The time commissioning of replacement and debugging can be controlled within one hour. It can greatly improve maintenance efficiency, reduce time of power failure, and ensure the reliable operation of the power grid.

**Table 1.** Process and time consuming.

Project name	Device debugging and configuration	Whole device replacement	Drive without power cut	Load test
time consuming (hour)	0.5	0.5	0.2	0.2

#### 4. Conclusion

Intelligent substations using local protection can truly realize new maintenance mode. Related information of protection devices can be centralized inspection, device status can be intelligently diagnosed, and it includes factory intelligent testing and replacing fast maintenance. However, the interface of intelligent management unit is still more complicated and the operation steps need to be further simplified in order to reduce the difficulty of operation and maintenance and the learning threshold. How too quickly and accurately complete field overhaul of local secondary equipment in the harsh outdoor environment (such as rain or snow and ice), it still needs to be improved in specific maintenance scheme follow-up.

#### Acknowledgments

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