

## PRACTICAL DEMONSTRATION OF HIGH-IMPEDANCE FAULT DETECTION TECHNOLOGY IN MV DISTRIBUTION NETWORK

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### ABSTRACT

*In MV distribution network, the probability of single-phase-to-ground fault is as high as 60% to 80%. Some of these faults can cause personal electric shocks or fire incidents, such as broken wires and wires discharged through the branches. They are classified as high-impedance faults (HIF). The existing faulty line selection and protection devices cannot reliably detect HIF. To ensure public safety, it is necessary to develop new technologies for HIF detection in distribution network. This article focuses on these issues, and introduces the research and demonstration of HIF detection technology in Fujian electricity Power Co. Ltd. In addition, artificial grounding tests were conducted to simulate ground faults through resistance, spherical gap, devices, wet earth and dry earth.*

### INTRODUCTION

The distribution networks are built on densely populated areas, where the vast majority of electric shock accidents occur. A total of 818 electric shock accidents occurred in Brazil's medium-voltage distribution network in 2012, and 292 people were killed. Among them, 10.2% were caused by construction, 8% by lines falling and illegal power jobs, the rest are caused by TV antennas, cranes, traffic accidents and so on. Similarly in China, according to the 2016 statistics, the deaths from electric shock are as high as 8000, of which the deaths in medium-voltage distribution network are estimated at 10%. The indirect contact of wires discharged through the branches and the step voltage caused by broken wires are the major causes of electric shock accidents. These faults are classified as high-impedance faults (HIF). Correct detection and protection of HIF are vital to prevent these kinds of electric shock accidents. In order to ensure social and public safety, it is necessary to further develop the performance analysis of HIF detection in the field applications [1].

This paper introduces the research and demonstration in three cities of Fujian province, including the ungrounded system in Quanzhou, the arc-suppression coil grounding system in Longyan, and the low-resistance grounding system in Xiamen. The paper also introduces the advanced technology in this field in China. The detection principle is based on a transient current algorithm as described in [1], which is not repeated here.

### SYSTEM ARCHITECTURE

In these demonstration projects, current transformers (TA) and centralised processing units (CPUs) are installed at different nodes along the 10kV overhead line. A new type of suspended photoelectric current transformer, housed in a fault passage indicator unit, is used to acquire the current signal from the 10kV line and transmit the information to the CPU through optical fibres. The primary current signal is induced into optical signal to realize photoelectric conversion. Since the CPU does not need to operate the circuit breaker, the hardware only requires low power consumption. Therefore, the method of capacitive power supply was selected to supply power to the CPU. The 10kV voltage is transformed into low voltage AC output, which also has the additional function of voltage sensing. The CPU performs functions such as analogue measurement calculations, derivation of zero sequence components for single-phase grounding fault detection etc. It communicates with the remote master station using wireless GPRS. This configuration is illustrated in Figure 2. In the primary substation, zero sequence current and voltage transformers are installed in the 10 kV outgoing cabinet for faulty line selection. The faulty line selection device at the substation cooperate with the photoelectric current transformers and the CPUs on the line to complete the whole on-line monitoring demonstration system.



I、New type of TA      II、Centralized processing unit  
Fig.1 New suspended photoelectric current transformer

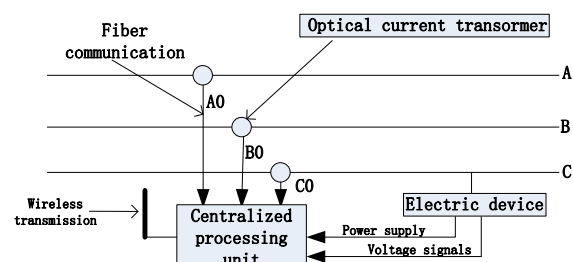


Fig.2 Overall architecture of the online monitoring terminal

## UNGROUNDING PROJECT IN QUANZHOU

### Overview of demonstration project in Quanzhou

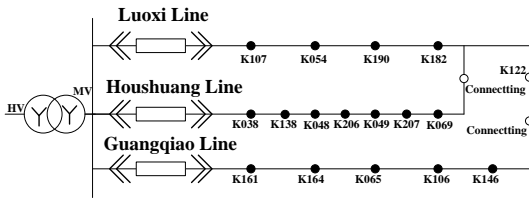


Fig.3 The ungrounded project in Quanzhou

The Quanzhou demonstration project covers 3 feeder lines. A total of 21 fault passage indicators were installed.



Fig.4 Site installation

### Actual fault incident

On September 28, 2017, the master station received a single-phase grounding fault alarm from Luoxi substation. The faulty line selection device identified that the grounding fault occurred on 10kV Hongshan Line (#612). The fault passage indicators showed that the fault was positioned between switches K207 and K069. After manual patrol, it was determined that it was a high impedance fault in a branch line at the back end of the K207 switch, caused by a lightning strike to the insulator. The fault was located by the system successfully.

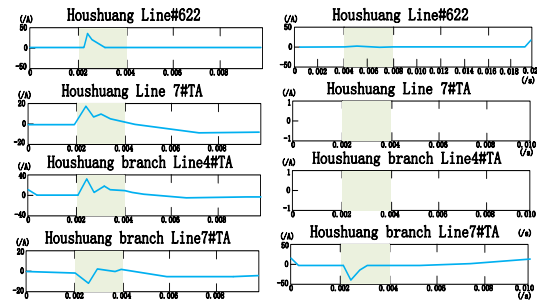
### Artificial grounding tests

15 different types of grounding tests were performed to the ungrounded system in Quanzhou. 11 tests were correct, with a success rate of 70%. The 5 failed tests were due to the large grounding resistance, resulting in fault current amplitudes less than the detection threshold. The minimum current amplitude of the system is 2.051A.

Tab.1 Test data of ungrounded system project

N.O	Grounding type	Equivalent resistance ( $\Omega$ )	Ungrounded		
			current (A)	result	
1	Resistance	500 $\Omega$	500	4.972	right
2		1000 $\Omega$	1000	3.689	right
3		2000 $\Omega$	2000	2.528	wrong
4		3000 $\Omega$	3000	2.051	wrong
5	Sphere gap	$\approx$ 200		8.164	right
6	Water	$\approx$ 500		4.775	right
7	Direct connect earth (moist)	$\approx$ 500		5.038	right

8	Direct connect earth (dry)	>1000	2.368	Wrong
9	Through branches	>1000	/	/
10	Through breakdown arrester	0	12.533	Right
11	components insulation breakdown	0	9.391	Wrong



I、Through 500 $\Omega$  resistance II、Through 2000 $\Omega$  resistance

Fig.5 Recordings from the grounded project

Two sets of recorded data were shown in Fig. 5. Houshuang line (#622) was successfully identified as the faulted line by the faulty line selection device, and the location function was started. When the artificial grounding resistance is 500 $\Omega$ , the magnitude of zero sequence current is greater than 10A, which effectively realizes fault location. However, when the resistance reaches 2000 $\Omega$ , the two terminal units located in the middle tower did not record the waveforms. Therefore, the system has failed to locate the 2000 $\Omega$  fault.

## ARC-SUPPRESSION COIL GROUNDING SYSTEM PROJECT IN LONGYAN

### Overview of the Longyan demonstration project

The Longyan demonstration project covers 7 feeder lines, of which 2 lines were installed with 21 fault passage indicators, as shown in Figure 5.

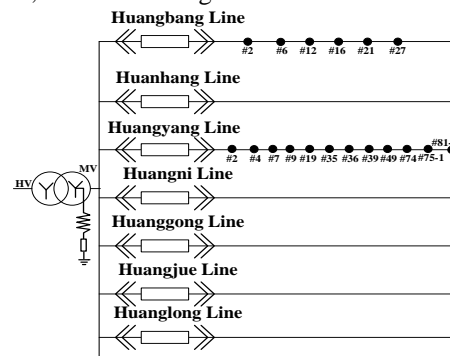


Fig.6 Arc-suppression coil grounding project in Longyan

### Actual fault incident

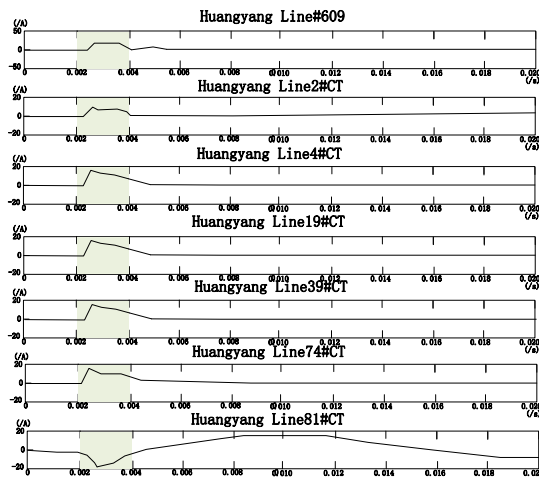


Fig.7 Actual fault recordings from the Longyan project

On December 28, 2017, the master station received a single-phase grounding fault alarm. The faulty line selection device identified that the grounding fault occurs on the 10kV Huangyang Line. The fault passage indicators showed that the fault was positioned between #74 and #81 switches. After manual patrol, it was determined that a high impedance fault caused by forest fire) has occurred on a T-connected outgoing line at #80 switch. Thus the fault was located by the system successfully. This is illustrated in Figure 7.

### Artificial grounding tests

A total of 8 different types of manual grounding tests were carried out on the Longyan site. 5 tests were correct, with a success rate of 62.5%. Compared with the ungrounded system, because of the over compensation of arc suppression coil, the characteristics of transient current are less obvious. Therefore the success rate is reduced. The main reason for the failures is still due to the fault current amplitudes lower than the threshold starting condition. If the devices were triggered correctly and the waveforms were sent to the master station, the fault location can always be done successfully.

Tab.2 Test data of arc suppression coil grounding project

N.O	Grounding type		Equivalent	Arc suppression coil	
			resistance	grounding	result
			(Ω)	I (A)	
1	resistance	500Ω	500	8.229	right
2	Earth resistance	Water	≈500	7.210	right
3		cement floor	≈200	9.978	right
4		Direct connect eart (moist)	≈500	9.05	right
5		Direct connect earth (dry)	>1000	-	wrong
6	Through branches		>1000	-	wrong
7	Through breakdown	arrester	0	11.946	right
8	components	insulation breakdown	0	15.25	wrong

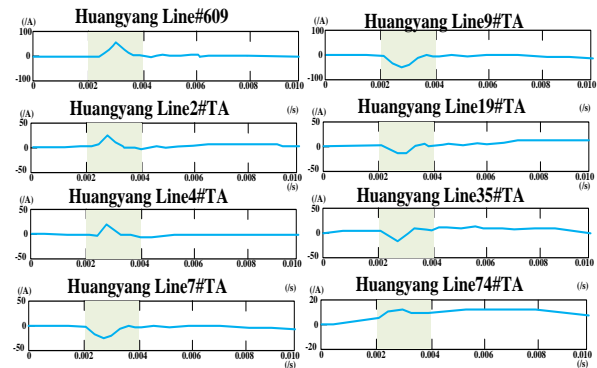


Fig.8 Artificial grounding test recordings from the Longyan project

Two sets of recorded data were shown in Figure 8. Case 1: simulated lightning strike fault conditions by arrester breakdown. Case 2: simulated the line breakage accident on the road side by single-phase grounding through cement floor. In both cases, the zero sequence current recording function can start normally, but Case 1 test failed to locate successfully. The main reason is that the abnormal signal in the system communication was not synchronized.

## LOW-RESISTANCE GROUNDING SYSTEM IN XIAMEN

### Overview of Xiamen's demonstration project

The demonstration project covers three 220kV overhead-underground hybrid power lines in Xiamen Island. They are the outgoing feeders from a low-resistance grounded 220kV Banlanshan Substation, as shown in Figure 9.

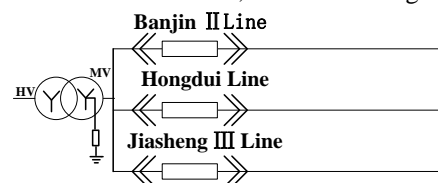


Fig.9 Low resistance grounding system demonstration project in Xiamen

### Actual fault incident

Because Xiamen is located in the special economic zone, the quality of equipment, the wide-spread application of cable transmission and the maintenance of power supply are better than the other two demonstration zones, and the probability of single-phase grounding fault is less. Currently, only two sets of data were captured, as shown in Figure 10. A 90ms record of zero sequence currents at 7 amperes was obtained in Banjin II line (# 936), the faulty line selection device determined that the fault has occurred in phase C of the Banjin II line. It was found that there was a transient fault in the substation, the reason for this failure is the aging of the C phase bushing insulation in the PT cabinet.

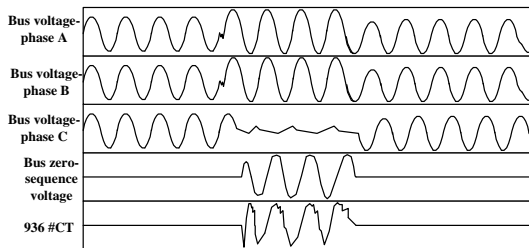


Fig.10 Recordings from the Xiamen demonstration project

- 27-32.
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### Manual grounding test

Since during the completion phase of this project, a government international conference was held in this area, the power outage could not be carried out. Therefore, no manual grounding test has been carried out in this area.

### CONCLUSION

The HIF in distribution network are the main cause of electric shock and fire accidents. In terms of the HIF diagnosis technology, China still lacks a comprehensive on-site technical solution. In this paper, aiming at the HIF detection technology, many demonstration projects have been carried out on site. The demonstration projects cover different grounding modes of MV distribution network. They have successfully achieved performance analysis through the actual deployment of faulty line selection and fault detection devices on site. The performance of HIF detection is about  $1000\Omega$  for Petersen-coil grounded system and  $2000\Omega$  for ungrounded system. Results of the practical demonstrations have verified the improved HIF detection ability of the new system. The projects provide lots of practical experience and information for the study of personal shock protection on a distribution network. Through this study, the author hopes to provide useful references for improving the reliability of power supply and the construction of a smarter grid.

### REFERENCES

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