Research on the Operation Specification of Arc Suppression and Resonance Elimination Device in Water Supply Distribution System

Jie Shen¹, Jianwei Sun¹, Zheming Wang¹, Wenbin Zhao²*, Jing Miao², Yunfei Wu²

¹Shanghai Pudong Veolia Water Corporation Limited, Shanghai 200127, China
²College of Electrical Engineering, Shanghai University of Electric Power, Shanghai 200090, China
*wenbinmax@163.com

Abstract—Arc suppression and resonance elimination device was used more and more widely in distribution power systems. The performance for limiting overvoltage and eliminating arc are better than arc suppression coil. But when the device not work properly, it would cause more great risk on the safe of the distribution network. It was analysed that an event of power failure of pair circuits distribution network installed with arc suppression and resonance elimination device. As an example, the simulation model was established with PSCAD software, and the working mechanism of the device was discussed. The overvoltage risk of the distribution system for water supply pump station was analysed. According to the analysing results, it is proposed that routine maintenance method and typical configuration of the device.

1. Introduction
With the rapid elevating of Chinese economy, the scale of cities is dramatic increasing. Increasing demands on water supply safety, reliability and quantity were increasing. Thus, distribution system of water supply was paid more and more attention. In recent years, with the expansion of the water supply and power distribution system, the use of cable outlets has become more frequent, and the rapid increase of the line-to-ground capacitive current has gradually weakened the arc extinguishing effect of the arc suppression coil. Moreover, the saturated of the iron core of the electromagnetic voltage transformer leads to the decrease of inductance value, which is easy to cause resonance overvoltage. This has become one of the killers of the rise of tripping rate. The Double circuit power loss accident of a water plant in Shanghai in 2020 is a sudden accident, which has caused potential safety hazard to the water supply and power distribution system. In this case, the arc suppression and resonance elimination devices came into being.

As a new type of device, the operation and maintenance guidance of the arc suppression and resonance elimination device is very leaking, and the insulation breakdown accidents caused by overvoltage are endless. Therefore, it is necessary to study the action mechanism of the arc suppression and resonance elimination device and the overvoltage generated during operation. This paper studies the accident process and the working principle of the arc suppression and resonance elimination device, and uses PSCAD to establish a simulation model of the water plant's power distribution network, analyses the overvoltage level in the network, and regulates the operation and maintenance of the device.
1.1 Analysis Of Accident
On May 7, 2020, it was informed by the power supply bureau that the water plant needs to stop the power supply of bus II at 6 a.m. on May 15th. At 5:28 am on May 15th, after stopping the 6kV bus II incoming line and closing the 6kV bus connection switch, the water plant restored the 6kV switchgear in Bus II. When closing the 6kV switchgear in bus III, the arc suppression and resonance elimination device was damaged, causing the 6kV incoming line switch in bus I to trip and the water outlet pump to trip. At 5:29, the water supply of the first water outlet pump was restored, and at 5:34, the water supply of the second water outlet pump was recovered. It is shown in Fig 1.

After the on-site troubleshooting test[8], it was found that the components of voltage transformer arrester cabinet in the 6KV bus II were short-circuited, which caused the bus I incoming switch to trip. The voltage transformer arrester cabinet was taken into service at the same time as other power distribution cabinets during the construction of the water plant in 2009. There is a set of arc suppression and resonance elimination devices in the cabinet. It has been in operation for more than ten years. The electrical test was carried out in April 2020 and the results were normal.

![Fig.1 Main circuit diagram of distribution network](image)

1.2 Working Principle Of The Arc Suppression And Resonance Elimination Device
(1) Composition Of Arc Suppression And Resonance Elimination Device
The main structure of the arc suppression and resonance elimination device is shown in the Fig 2.
The device is a complete set, including voltage transformers, overvoltage protectors, intelligent microcomputer controllers, fast current-limiting fuses, fast vacuum contactors, harmonic elimination resistors, high-energy voltage limiters, high-voltage isolation switches and so on.

(2) Analysis Of The Working Principle Of The Arc And Harmonic Elimination Device

When there is switching overvoltage or atmospheric overvoltage in the system, the combined type of overvoltage protector limits the overvoltage within the allowable range of system insulation[9].

When a single-phase grounding fault occurs in the system, the microcomputer controller named TWK detects and analyses the three phases voltage of the system through the voltage transformer PT to judge the nature[10]. Then it will take the following measures according to different features in different faults[7].

If the ground fault is a stable metal ground[11], TWK will immediately sound an alarm. Meanwhile, it will indicate the nature of the ground fault signal and the specific location of the ground. The alarm signal is sent out simultaneously by the communication interface and the relay dry node.

If it is intermittent arc-earth fault, TWK will immediately send out an action signal to cast the high-energy voltage limiter TRV into the fault phase, limiting the highest peak value of the fault phase recovery voltage to about 50% of the phase voltage. Simultaneously, arc energy will be released, so that the arc will not burn again after the current crosses zero. Then, the purpose of rapid arc suppression will have been achieved. While the device is extinguishing the arc, the voltage limiter works to limit the arc grounding overvoltage generated by the system to a very low level, so as to ensure the safety of the system. The device's microcomputer controller TWK simultaneously records the operating time, the nature of the fault, and the location of the fault, and communicates the recorded information to the background processing machine.

When it happened to resonate, the device instantly puts a high-energy voltage limiter TRV on the lower voltage phase to reduce the three-phase ground voltage of the system to the range that the insulation can withstand, so that the voltage transformer can automatically enter the linear region. At the same time, the TRV makes the resonance disappear immediately by absorbing and discharging the resonance energy. Due to the input of the high-energy voltage limiter TRV, the oscillation parameters of the zero-sequence loop of the system are changed to ensure that resonance no longer occurs. If the
resonance still exists or reoccurs at the moment when the TRV exits, TWK will issue a command to insert a power resistor into the secondary open delta winding of the PT to eliminate the resonance.

From the above analysis, it can be seen that the main arc and harmonic elimination function of arc suppression and resonance elimination device is to use a vacuum contactor to put in a high-energy voltage limiter to limit the voltage and energy discharge, so as to achieve the purpose of arc elimination and resonance elimination.

2. Simulation Analysis And Results

2.1 Analysis of the Overvoltage Level of a Distribution Network

Build the system structure model as shown in Figure 1. The power source is 35kV. After the main transformer, the voltage level becomes 6kV. The device is applied to the side of 6kv. There is no soft start before the motor, and the form of direct switching is used.

(1) Simulation analysis of operating over-voltage of closed air line

In the actual closing operation, factors such as the closing angle of the line, the capacitance value of the reactive power compensation, and the size of the cable length will affect the overvoltage level of the line. Using PSCAD to scan the combination of different influencing factors, you can study the system. The overvoltage of the unloaded line is closed at the cable who is 4.5km long at a 90-degree angle, and the maximum value is 1.93p.u without reactive power compensation, as is shown in the Figure 3.

![Fig.3 Overvoltage level when no-load circuit is closed](image)

(2) Long-term voltage transmission machine over-voltage horizontal simulation analysis

In the same way, using the Multiple Run element to scan the model, you can get the overvoltage level of the long-cable line in the case of different phase angles and different reactive power compensation\[1\]. As shown in the Figure 4, the maximum overvoltage level is 1.84p.u.

![Fig.4 Overvoltage level when turning on the motor](image)

(3) Simulation Analysis of Resonance Overvoltage Level

The system is simulated and analyzed for resonance overvoltage\[3\], and the overvoltage level during system resonance is obtained, as shown in Figure 5. The overvoltage level has been as high as 3.4p.u. Resonance occurs when the cable length exceeds 2km.
Through the above analysis, it can be seen that the overvoltage level reaches 1.93 P.U. when the no-load line is closed, but only 1.84 P.U. when the motor is turned on. The two are not more than three times of the international standard related to switching overvoltage. But the resonance overvoltage has exceeded the standard \(^4\). Therefore, it is not safe when the arc suppression and resonance elimination device is operating.

2.2 Research on Action Mechanism of Arc Suppression and Resonance Elimination Device

In order to study the operation mechanism and overvoltage suppression effect of the arc suppression and resonance elimination device, PSCAD is used to model the arc suppression and resonance elimination device.

(4) Device simulation model

As shown in the Figure 6., when overvoltage occurs, the arc suppression and resonance elimination device extracts the monitoring voltage on the PT. The overvoltage circuit is selected through the comparison of overvoltage level setting, and a harmonic elimination resistor is placed in the corresponding fault phase to eliminate arc and harmonic\(^5\).

(5) Risk analysis under the condition of the device abnormally operating

The overvoltage during resonance of the system\(^12\) is shown in Figure 7.

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Fig.5 System resonance overvoltage level

Fig.6 PSCAD model of arc suppression and resonance elimination device

Fig.7 Resonance overvoltage level when the arc suppression and resonance elimination device is not put into use
After the arc suppression and resonance elimination device is put into operation, the overvoltage suppression is shown in Figure 8.

![Figure 8: Resonance overvoltage level when the arc suppression and resonance elimination device is put into use](image)

It can be seen in Figure 8 that the arc suppression and harmonic suppression device has a good inhibitory effect on the resonance overvoltage when it operates correctly.

When the arc suppression resistance is put into operation for a long time, it means the device fails to exit correctly, and the insulation breakdown then occurs, the system will cut down. It is shown in Figure 9.

![Figure 9: The overvoltage level when the arc suppression resistor of the arc suppression and resonance elimination device is broken down](image)

If the action limit value of three-phase voltage setting is not correct, the arc suppression and resonance elimination device should be put into operation without overvoltage, which could lead to breakdown as shown in Figure 10.

![Figure 10: The overvoltage level when the arc suppression and resonance elimination device malfunctions](image)

When the arc suppression and resonance elimination device acts, if the phase is not correctly selected due to the setting error, the arc suppression device will cut down the sound phase wrongly. At the same time, voltages of the two other phases would rise a little, which is equivalent to the condition of short circuit between the two phases as shown in Figure 11.
When two arc suppression and resonance elimination devices are installed on the same bus, if the resonance phenomenon occurred, the two devices would act at the same time, which could aroused incorrectly action of relay protection.

Giving a delay time of 0.55s, when one device exits and the other device is still running, which it is equivalent to a single-phase grounding fault. It is shown in Figure 12.

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3. Conclusion Introduction
According to the previous analysis, the arc suppression and resonance elimination device can release energy and suppress the overvoltage level of the system after it is put into operation. When the length of the cable exceeds 2000 meters, the arc suppression and resonance elimination devices shall be installed. However, the means of arc suppression and resonance elimination mainly depends on the input of resistor by air switch, which will lead to the failure risk of operation and maintenance: if the air switch is not opened or closed in time, the harmonic elimination resistor and other components will be breakdown due to aging, humidity or other factors. Therefore, the secondary resonance elimination part of microprocessor resonance eliminator should have measures to prevent the device from frequent action when intermittency electric when intermittency electric arc’s earthing and electromagnetic voltage transformer are damaged. Its selection can follow the following principles:

a) When the voltage is unbalanced or the zero sequence voltage exceeds the protection setting value after the primary harmonic eliminator is adopted;

b) When the primary neutral insulation of electromagnetic voltage transformer is damaged due to the use of primary harmonic eliminator;

c) Protection line break resonance or ferromagnetic resonance of electromagnetic voltage transformer only under two-phase operation

What’s more, the microcomputer type harmonic eliminator should be installed on the main bus, and multiple microcomputer harmonic eliminators should not be configured on multiple terminal buses.
For the distribution system without overhead lines, the microcomputer type harmonic eliminator does not need to be equipped with arc suppression function.

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