An Online Monitoring System for Salt Deposit Density and Non-soluble Deposit Density of Power Transmission and Transformation Line Insulator

Su Hainan[1], Du Jikuan[1], Li Junming[1], Liu Yu[2], GaoYucong[3], Li Xueyan[4], Du Xingkai[1], Yang Sen[1], Ma Jian[5], Gu Guoxing[6]

[1]Dandong Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

[2]Harbin Power Supply Company, Heilongjiang Electric Power Company Limited, State Grid, China

[3]State Grid China Power Finance Co.,Ltd.,China

[4]Shibei Power Supply Company, Shanghai Electric Power Company Limited, State Grid, China

[5]State Grid Yingda International Holding Group Co.,Ltd.,China

[6]Anshan Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

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Abstract: The external insulation performance of power transmission and transformation line equipment has a major impact on the operational safety of the power grid. A large number of insulators are incorporated in power systems, and the surface pollution and moisture will seriously affect the electrical characteristics of the insulator, and the dirt accumulated on the surface of the insulator will cause insulator flashover breakdown, affecting the power transmission and transformation line reliability, endangering the operational safety of the grid. In recent years, with the rapid development of China's economy, the old industrial bases in Northeast China saw revitalization. However, the revitalization caused increasingly serious environmental pollution. In particular, haze takes place more frequently, which has seriously affected the anti-pollution of transmission line insulators. Moreover, insulator pollution flashover often results in large and serious power outage.

1. Introduction

The transmission line is the key channel to ensure the stable power supply from the power grid. The important indicator of the smart grid is to improve the efficiency of the grid operation and reduce the power outage of the line. One of the important indicators is to prevent the pollution flashover in improving the reliability of power supply. Pollution flashover is the dirt attached to the insulator surface of electrical equipment, and the soluble matter of the dirt gradually dissolves in water and forms a conducting film in humid conditions, and the film greatly reduces the insulation of the insulator and causes a strong power discharge with the electric field force. The three elements necessary to trigger pollution flashover: insulator surface pollution, humidity, and voltage. Therefore, destroying one of the three elements can prevent the occurrence of pollution flash.

2. Causes of a pollution flashover accident

With the increasing promotion of high-voltage and ultra-high-voltage transmission and the continuous improvement of line voltage levels, insulator pollution flashover becomes increasingly dangerous. According to statistics, under the existing voltage level, pollution flashover has become more dangerous than lightning stroke. There are three main reasons for the pollution flashover accident: 1, environmental pollution in China is rapidly worse, which is related to local industrial structure; 2, the insulation level of the electrical equipment does not meet the local pollution requirements; 3, power sectors lack effective technical means to detect equipment pollution. In the area where the transmission line passes, the insulators in operation gradually accumulate a layer of

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pollutants on the surface, which is due to the atmospheric environment such as nitrogen oxides and particulate dust. In dry weather, these insulators with dirt on the surface maintain a high level of insulation, and the discharge voltage is close to that of the insulators in a clean, dry state. However, when there is humid weather, the pollutants on the surface of insulators absorb moisture, causing the electrolyte in the pollution layer to dissolve and ionize, resulting in an increase in conductance. In this case, the insulators leak more surface current. Under the impact of the shape and structure size of the insulator and the uneven distribution of the surface of the insulator, and moisture differences, the current density of each part of the surface of the insulator varies, and as a result, a drying zone is formed at a portion where the current density is relatively large. A drying zone makes the voltage distribution on the surface of the insulator even more uneven, and the drying zone carries higher voltage. Therefore, when the electric field strength is sufficiently large, the insulator makes an electric discharge and then creates a local electric arc. At this time, the surface discharge model of the insulator corresponds to a local arc in series with a layer of resistance. The local arc might be extinguished or be enhanced. When the local arc continuously takes place and becomes enhanced beyond a critical state, the arc runs through the two poles to produce a flashover.

3. Significance of insulator salt deposit density test

It is clearly stipulated by relevant national standards that the classification of the external insulation pollution level of transmission and transformation equipment should be based on pollution flashover, operating experience, and the salt deposit density on the surface. Therefore, salt deposit density is the only parameter that can be quantified. At present, the principle of external insulation configuration of transmission and transformation equipment is implemented on the basis of the departmental standard GB/T 16434, and is adjusted in time according to the approved distribution map of the pollution area. In reviewing the distribution map of the pollution area, the important basis for drawing and revision is to sort out and analyze the salt deposit density measurement data of the past years. At the same time, the transmission line should be cleaned on a regular basis, according to the salt deposit density measured in the monitoring points, and the characteristics of saturated pollution of insulators should be studied, and the pollution area of power grid should be divided by saturated pollution. Laboratory research should be conducted to clarify the pollution characteristics and creepage distance effective coefficients of insulators under various pollution and arrangement conditions. Also, the horizontal design curve of external insulation in various polluted areas should be proposed. In the end, efforts should make the transmission line free from cleaning work, or reduce cleaning work, or ensure state cleaning. In doing so, the transmission line should be free from large-scale human cleaning, thereby making the anti-pollution flash of the power grid no longer subject to climate. Therefore, salt deposit density measurement is of great significance to the production and safety of the power sector.

4. Development of online monitoring system for salt deposit density

At present, a major project of the pollution flashover prevention operation of the transmission line is to detect the salt deposit density value and the non-soluble deposit density value of the insulator every year. The traditional detection method is to suspend an insulator string on the tower in advance. After one year, the insulator string is taken off for scrubbing, and then the salt deposit density meter and the non-soluble deposit density meter are used for measurement. In this case, a large amount of work is required, and the detection is carried out in a long cycle. Therefore, the detection process is cumbersome and is highly limited. This method fails to fully consider the influence of pollution speed, and cannot accurately guide the reasonable arrangement of the outer insulation creepage distance ratio. Moreover, the measurement results are highly dispersive, and therefore it is difficult to determine the measurement period reasonably. In addition, the working group of the national high-voltage anti-pollution flashover network has now clearly stipulated that the pollution map should be modified based on the saturated salt deposit density. However, the traditional method cannot obtain the saturated salt deposit density of the equipment. Moreover, it cannot monitor environmental changes near the line in real time. Therefore, it is necessary to develop an on-line monitoring and analysis system to monitor salt deposit density and non-soluble deposit density in the air in real time, in order to obtain real-time and accurate measurement of salt deposit density and non-soluble deposit density. In doing so, this system allows personnel to take effective steps to prevent line pollution flashover, providing a technical basis for anti-pollution flashover, meeting the demand of transmission line insulator anti-pollution flashover, and opening up new markets.

4.1 System Introduction

The online monitoring system for insulator salt deposit density and non-soluble deposit density of power transmission and transformation line is mainly composed of instrument mechanical structure and data monitoring center and data monitoring terminal. It is a large intelligent real-time salt deposit density and non-soluble deposit density monitoring system capable of temperature measurement and control, pressure measurement, conductivity measurement, and sampling control. The system networking is very easy, and it can enable the monitoring center to be managed based on multiple levels, making points monitored at different locations at the same time. The data acquisition terminal is installed near the insulator of the transmission line or near the framework to have real-time monitoring of the temperature and humidity of on-site pollutants (salt deposit density and non-soluble deposit density). The monitoring data is transmitted to the server collectively through the Internet of Things technology and the TCP protocol. Then, the salt deposit density of the monitoring point is checked in real time through the web, in order to deal with the unreliable insulator as soon as possible, thereby preventing pollution, shown in Figure 1.

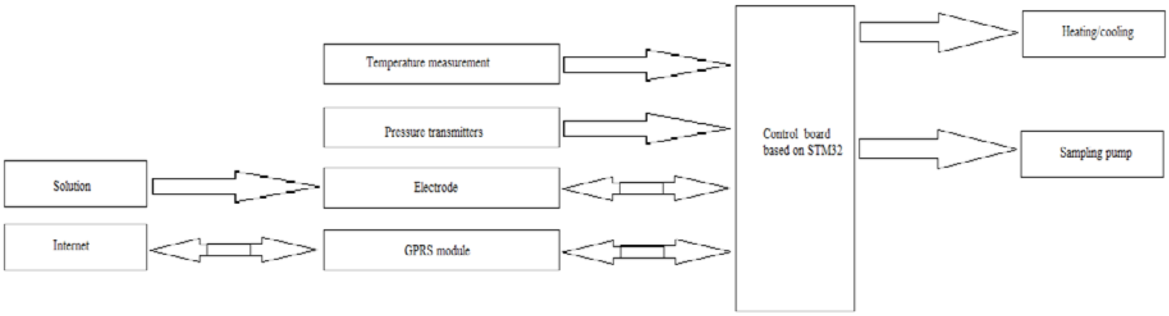

Figure 1 System principle schematic diagram

4.2 Monitoring principle

The core component of the online monitoring system for insulator salt deposit density and non-soluble deposit density of power transmission and transformation line is a sampling head, with built-in long-life pump, driven by brushless electrodes. A piece of large-volume glassware is used as the sample cell. The upper end of the sample cell is connected to an air inlet and an air outlet, and the air inlet pipe is connected to the water, helping the organic matter in the air to sufficiently dissolve in the water. The other outlet pipe is placed on the water, with a conductivity measurement port, and the conductivity test is with a 1.0 electrode, which can be immersed in water for a long time, and the measurement range is 10～10000.0 uS/cm. A unique injection sampling system separates the airborne material and then dissolves it into water, and then tests for salt deposit density and non-soluble deposit density. The pump and tube draw air into the measurement area, and the particles in the air are separated by a solid separation device, and the separated air is separated once again to ensure that all particles of the gas are filtered into water, and after sufficient dissolution, measurement and analysis are conducted as shown in Figure 2.

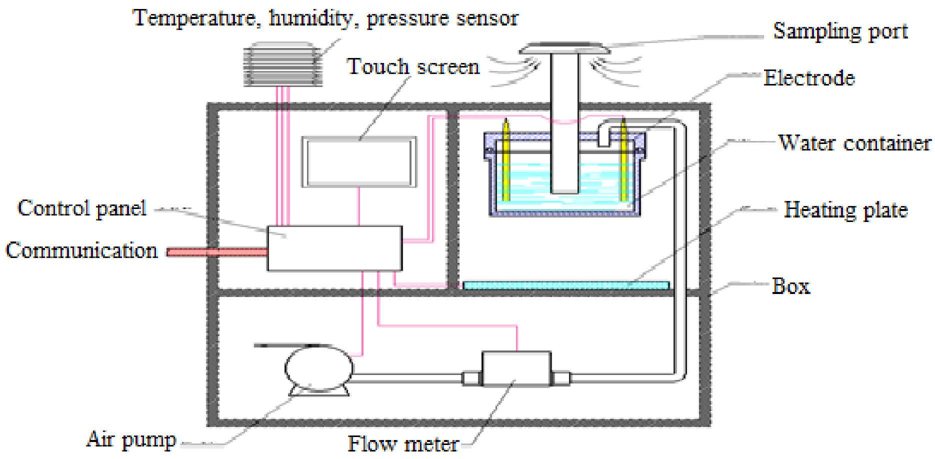

Figure 2 Working principle schematic diagram

4.3 Features

(1) Easy to use and operate. The monitoring center software interface is friendly and easy to learn.

(2) System maintenance is easy. The system is friendly with faults and errors, and is capable of automatic system recovery, and provides remote maintenance.

(3) Printing management. The system is capable of printing monitoring data and curves.

(4) Early warning capability. When solid, liquid and gas particles interact simultaneously with severe meteorological conditions such as fog, dew, drizzle, melting ice, melting snow, and the insulator pollution is beyond the limit value, the system can sound the alarm and inform personnel via computer and phone, thereby reducing the risk of pollution flashover, and improving the reliability of the power supply system. The alarm information is composed of geographical information and the value of the pollutants at the monitoring points.

(5) Equipment protection. The data monitoring terminal chassis is well enclosed and is lightning-proof, rain-proof and dust-proof. The shape design effectively avoids the influence of the current collecting and discharging in the high electric field environment.

(6) On-site installation and maintenance are easy. The data monitoring terminal adopts a modular design. The upper part is the sensor; the lower part is the main control box, which is convenient for on-site assembly and disassembly.

(7) Charging power supply. The data monitoring terminal is charged by the battery to ensure the normal operation of the device.

(8) Data monitoring center. The computer is specially designed for the monitoring of salt deposit density and non-soluble deposit density. The system is capable of long-term stable operation and large data calculation.

4.4 Application

Power transmission and transformation line. Salt deposit density and non-soluble deposit density measurement are to be carried out every year as part of insulation supervision according to the precautionary regulations, as stipulated by GB/T16434-1996 *High-voltage Overhead Line and Power Plant, Substation Environmental Pollution Area Classification and External Insulation Selection Criteria*, and the State Power Corporation Safe Transmission [1998] No. 223 on revised *Electric System Pollution Area Distribution Map* and *Electric System Pollution Area Distribution Map Regulations*. In principle, monitoring points should be made every 5 to 10 km to monitor salt deposit density, away from farmland and hills. For severely polluted areas and areas with complex dispersive pollutants, more monitoring points could be made. They are made to scientifically guide the cleaning cycle of the transmission line.

Substation. The data acquisition terminals should be arranged at the four sides of the substation, and the monitoring center can be placed in the substation control room or the power supply company office building. The monitoring center workstation records the external insulation parameters of different equipment in the substation, and calculates the actual external pollution deposit (salt deposit density) of the equipment, based on the monitored salt deposit density and non-soluble deposit density.

5. Conclusion

The online monitoring system for salt deposit density and non-soluble deposit density of power transmission and transformation line has been tested for 1 year in 2018 by Dandong Baite Instrument Co., Ltd. and Heilongjiang Power Supply Co., Ltd. Therefore, a large number of on-site operation data has been obtained. The results found that the measurement data error of the online monitoring system for salt deposit density and non-soluble deposit density of power transmission and transformation line is within the 1.17%-2.85% range, as compared with that by traditional manual methods, which is in line with the requirement for a measurement error within 3%.

At present, the online monitoring system for salt deposit density and non-soluble deposit density of power transmission and transformation line has been put into use for trial. More operational experience and the active efforts of scientific and technical personnel will further improve the system that will play an increasingly important role in protection and warning in the safe operation of the power grid.

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