The Research development of the Filthy detection technology for Transmission line Insulators

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Abstract. According to the testing methods, filthy degree measurement can be divided into direct detection and indirect detection. This paper reviewed the development history of impurity detection and the current status quo at home and abroad. On the basis of existing research, impurity detection technology application situation, analysis their respective advantages and disadvantages, summarized power system layout is structured and disadvantages. Impurity detection to seek new breakthroughs to integrated a variety of integrated pollution direct detection methods, build a real-time monitoring system, realize the insulator filth adherent state of timely, accurate, in order to reduce the pollution flashover accident and provide support for power grid external insulation protection.

1. Introduction

Affect the performance of insulator, and mainly product electrical insulator and pollution degree of characterization methods, the characteristics of paint pollution area and the external insulation configuration, transmission line insulator pollution flashover accident cause serious damage to the safe operation of power grid. In the increasingly severe atmospheric environment pollution, transmission line insulator will face more serious threat of pollution flashover [1-3]. Many factors influencing the insulator pollution pressure of lightning, the domestic and foreign scholars have carried out extensive research [4,5], the beginning of the 20th century to the attention of the people, by the 1950 s, the world pollution flashover accident is very serious. Obenaus pollution flashover model is put forward in the 1950 s, researchers by detecting the reaction product, reveal the unclean degree of voltage, discharge current, conductivity and temperature rise of the image information, strives to reflect the state of transmission line insulator impurity attached effectively, thus provide data support for the master pollution area distribution power system.

Therefore, the domestic scholars to accumulate dirt real-time detection of various improved method [6], and widely used. Insulator impurity detection technology at home and abroad is reviewed in this paper the present research situation and development trend, including the running state of the insulator methods for characterizing the filthy, filthy adherent amount, artificial contamination test, test method and the actual runtime of grey state relations and unsolved problems, such as classifying insulator impurity detection technology, puts forward the future insulator defile the real-time and effectiveness of the representation method. To master the real-time filthy state, understanding of insulator covered ash
characteristics, filthy areas outside the selection of insulation and the determination of the future research emphasis has certain reference value.

2. The Classification of insulator impurity detection technology
The existing technical method is based on the detection method can be divided into: one is direct detection. Directly testing filth deposition of polluted insulator or surface layer (such as equivalent salt density, conductivity, leakage current, the dirt layer deposition sludge image) to obtain product polluted insulator state data value, the influence of polluted insulator electric performance; The second is indirect detection. Set up near the insulator detecting objects, such as optical sensing quartz rod. Through analysis to detect the state surface covered ash, or using the product of polluted insulator infrared, ultraviolet, features such as amplitude value, indirect reflect insulator filthy adherent state, combined with the artificial contamination test, analysis of data and the relationship between the impurity attached indirectly, transmission line insulator impurity attached quantity is deduced, for insulation product testing.

3. Direct detection method
International conference on power grid the 33rd committee recommended the equivalent salt density, surface fouling layer conductivity, leakage current pulse counting method, the maximum leakage current method and insulator flash a gradient method. IEC and IEEE recommended using the method of equivalent salt density, China and Japan has adopted this method. This is also mostly USES the equivalent salt layer conductivity, leakage current, sludge as a filthy characteristic.

3.1. Equivalent salt deposit density (ESDD)
Equivalent salt deposit density (ESDD) is of ionization material quantitative measurement of conductivity performance, dissolved in a certain volume and the actual unclean in distilled water under a certain temperature, to dissolve the NaCl to the same volume and same temperature of the distilled water, measure the conductivity of the two kinds of solution, respectively. When a certain amount of NaCl solution conductivity exactly equivalent hydraulic conductivity, said the number of conducting material in the liquid soap equivalent to the amount of NaCl. Again this is obtained by dividing the number of milligrams of NaCl insulator surface area, close to the desires of the equivalent salt.

![Figure 1. The relationship between the pressure and the ESDD fouling lightning.](image)

Equivalent salt method is one of the biggest advantages is straightforward, but there are all kinds of faults [7]: a secret, the equivalent salt generally need to remove the insulator from the tower to the ground to test the measurement again, even in the process of disassembly or transportation, impurity substance on the surface of the insulator will inevitably some losses due to scratches and lead to inaccurate measurements; Second, the equivalent salt density method needs to be the filth of the insulator surface cleaning, is a destructive test method, can't for long-term monitoring of the same product pollution characteristic of insulator; Three, the equivalent method of salt density measuring salt need to lines or substation blackout, consuming a large amount of manpower and material resources; Four, the equivalent salt method equivalence problems.
3.2. Leakage current method
Domestic represented by Tsinghua University and the University of Chongqing, represented by Sweden and Japan abroad, through a lot of filter test and outdoor investigation and analysis on the leakage current caused by the influence of different level \([8,9]\), impurity attached condition. So judging leakage current product pollution is the most common way of testing and studying the characteristics of polluted insulator leakage current is of great significance.

Now let the cat out of the current research mainly focused on feature selection, data analysis and model building, etc. Characteristics, which is the core content, is directly related to the subsequent flashover warning, aging condition monitoring, the effectiveness of the surface state monitoring. Chongqing University to extract the three characteristics of the leakage current, average, maximum and RMS value of the standard deviation of the leakage current, established three characteristics and the regression equation between different pollution levels and 3 characteristic and environment relative humidity and the amount of working voltage for the input, the pollution level for the output of neural network model \([8]\). Japan Sidthik selected the leakage current, maximum, and standard deviation of the average of the three characteristics, establishes the three characteristics, temperature, pressure and voltage as the input of the neural network model of prediction pollution levels \([9]\). China Electric Institute has chosen the effective value of leakage current, the leakage current peak value and pulse number of the three characteristics, use the method of least squares support vector machine (SVM) was established by three characteristics and environmental temperature and humidity for the input amount of intelligent model, predict pollution levels \([10]\).

![Figure 2. Leakage current test system schematic diagram.](image)

After recent years of engineering application, the leakage current test parameters on the impact of transmission lines and itself the problem: one, the leakage current need to borrow the transmission line voltage of insulator discharge, affect the normal operation of line; Second, on-line monitoring device for the most of the research at home and abroad are based on the leakage current characteristics of development of saturated humidity, due to the severe leakage current is affected by humidity table, factors such as the rain make insulator surface humidity increase sharply, product pollution is very serious on the surface of the insulator leakage current will increase sharply. Even if monitoring leakage current online monitoring system to the change of leakage current, signal the pollution flashover accident alarm, relevant staff cannot take action to prevent pollution flashover accidents in a timely manner. Leakage current of insulator surface fouling monitoring effect is better, the applicable scope is broad, can be applied to ac/dc transmission lines, but do not apply to the electromagnetic interference is more serious and relatively dry areas.

3.3. Product image analysis
In recent years, with the development of machine vision technology, the non-contact measurement, wide spectral response range, long working hours, in a numerous advantages of higher precision, and more
and more get attention Catenary insulator contamination detection based on machine vision system [11,12]. The first to use SURF algorithm for catenary insulator features extraction and establish the sample library, for the identification of insulator. Then use the binocular vision system, for accurate positioning insulator. After using the features extracted by catenary insulator surface filth, classify filth. On this basis, using HSV to dimension reduction of characteristics, by means of cluster analysis to divide the pollution level. Finally, the use of database system will receive the information to collect, record. Thus, based on the analysis of machine view product pollution technology is one of effective means testing insulator polluted degree of support.

4. Indirect testing technique
USES equivalent salt layer conductivity, leakage current, sludge the disadvantages of traditional direct detection technology is different, can't fully effective detection of insulator pollution status of surface area, so the scholars represented by optical sensing technology was conducted by indirect detection research and application, get the evaluation results.

4.1. Optical sensing detection
Filthy existence will effect on transmission path and the flux of light, the light novel measurement method, advanced sensor technology, has realized the insulator salt density of power transmission and transformation equipment online, real-time monitoring, in China's northern, central, southern hanging on a large scale network run [13].

But after the operation of impurity detection in optical sensing technology appear a series of problems, mainly reflected in: a, optical sensing technology to measure the output is not charged reference insulator ESDD and NSDD [14].

![Image](Figure 3. Leakage current test system schematic diagram.)

The shape of optical waveguide and material and insulator differs a lot, it directly affects the adhesion of uncleanness, and make the optical waveguide surface pollution situation and the insulator surface pollution situation of comparability. Directly affect the rainfall erosion factors such as the amount of insulator surface pollution of different materials and shapes of optical waveguide and the insulator erosion effect is very different, which makes optical waveguide on-line monitoring system for monitoring the pollution degree and the product of insulator larger error between the actual product pollution degree, and the resulting error correction is difficult, limiting the scope of application of on-line monitoring system for optical waveguide. Second, due to all the year round such as synthetic monsoon insulator surface pollution distribution factors exist, and the pollution flashover accident mostly along the product pollution serious insulator surface. Light sensor, salt of on-line monitoring system can't effectively reflect the possibility of pollution flashover accidents. Third, in the actual
operation, due to the effect of electric field force of the ac/dc lines, dc lines more easily than ac line product pollution. Light sensor, salt density on-line monitoring system is more suitable for ac transmission line insulator impurity level monitoring, the polluted degree of dc transmission line insulator monitoring will there is a big error. It also limits the on-line monitoring system of optical waveguide in the application of dc transmission lines.

4.2. Microwave radiation detection

Microwave radiation method using insulator in the microwave radiation characteristic differences of impurity levels. Any objects have been above absolute zero radiation, radiation frequency range is very wide, when the object surface is unclean, emissivity with filth and filth properties change, change is more obvious when wet, dirty layer and objects of electromagnetic radiation can be measured by Planck's law.

On insulator contamination of the microwave radiation characteristics research, Germany by using microwave radiometer is proposed to detect the filth of the insulator, its principle is a radiation characteristic difference of different material is different, according to the differences in microwave insulator surface unclean to detect insulator polluted level [15], north China electric power university and other domestic from the complex dielectric constant of unclean, analyze its relationship with the radiation temperature on the studies the real part and imaginary part of dielectric constant and the relationship [16] between water content, salt content, set up the relationship between radiation light temperature and salt, insulator filthy three layer medium model is established.

4.3. UV pulse detection

Insulator discharge with a light phenomenon, which contain certain uv light, clean insulator discharge is very few. Polluted insulator is often accompanied by discharge when humidity is bigger. Insulator with discharge conditions change in the process of uncleanness, and can take advantage of the insulator discharge difference to detect filth. Ultraviolet imaging technology as a non-contact charged detection method, detect insulator external discharge, convenient for many reasons, but because of the insulator discharge through large-scale, system test is necessary.

Product the unclean insulating surface discharge and product related, so the use of ultraviolet imaging to distinguish impurity levels. In uv pulse method to capture product insulation abnormal discharge pulse, use it to diagnose the filth of the insulator level [17]. But different impurity state (including the impurity distribution, filthy salt density and humidity) of the insulator with no obvious difference between uv pulse number and affected by the applied voltage and humidity of the air, filthy state for insulator leakage current method is better than precision.

5. Indirect testing technique

With the development of the impurity detection technology, integrated a variety of testing methods and development of new detection sensor is gradually become a research hotspot. Such as leakage current detector based on LED optical fiber sensing [18], leakage current detector based on the technology of cantilever beam, new technologies, such as [19]. Current passive intensity modulated optical fiber current sensor and other new type of leakage current of the detector research at home and abroad research is in focus development [20]. Machine vision technology at the same time direct detection methods such as collection of non-contact measurement, wide spectral response range, long working time, numerous advantages of higher precision, catenary insulator contamination detection based on machine vision system get application in high-speed rail, urban subway.

Through the selection of appropriate correction model correction coefficient, which can effectively improve the prediction precision of combination forecast model, make the ESDD predicted results of actual power system engineering of insulator has more effective pollution prevention work of guiding significance to the literature.

According to the technique and experience of the past and single factor to obtain data, and to establish the model of adaptive will be more and more poor. With the technology development, product of
insulator pollution comprehensive variety of direct detection is an effective way to achieve long-term effective degree of impurity detection.

6. Conclusion

Insulator pollution influenced by outside factors, single factor cannot effectively reflect the actual operation state of impurity attached condition. Existing insulator running impurity characterization, filthy attached quantity detection method, insulator artificial contamination test, and line working relationship with the model and so cannot be completely real-time, accurate to obtain product pollution characteristic of insulator in ac, dc field, is unable to update the unclean area distribution, lead to errors occurring in transmission lines outside insulation protection configuration. Were reviewed in this paper all kinds of detection means and methods of the transmission line insulator, filthy, on the basis of their respective advantages and disadvantages, seek breakthrough of real-time detection, and designed to a variety of direct detection method, realize the product pollution timely, accurate detection, for the drawing of power system in real time to distinguish the layout provides reliable means of support.

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