Simulation Analysis of Voltage Distribution of 500kV Degraded Magnetic Insulator String

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Abstract. Insulators are important power grid equipment and key components to ensure electrical insulation performance. Porcelain insulators with reduced insulation performance are generally low or zero, and are broken down under lightning overvoltage or even normal operating voltage. The thermal effect generated by the strong power frequency fault current flowing through the porcelain insulator will often cause deterioration of the porcelain insulator. The iron cap exploded, causing serious accidents such as stringing of insulators and grounding of wires. If there are continuous multiple pieces of zero-value insulators in the insulator string, the voltage of the insulators around the zero-value insulators will increase compared to normal conditions, and the normal insulators farther from the zero-value insulators will be less affected. If there are multiple consecutive zero-value insulators at different positions in the insulator string, if the number of zero-value insulators in the insulator string is large enough, and the distribution positions are more diffuse, the voltage of the entire string of insulators in the insulator string will be biased as a whole high.

1. Introduction

Insulators are important power grid equipment and key components to ensure electrical insulation performance. At present, porcelain insulators, glass insulators and composite insulators are widely used due to their respective characteristics. Among them, porcelain insulators have the longest history of application. Porcelain insulators may suffer from insulation performance degradation due to long-term exposure to the electrical and mechanical load of the line, wind, rain and thunder and other harsh natural environments, or due to the quality of their own equipment. Porcelain insulators with reduced insulation performance are generally low or zero, and are broken down under lightning overvoltage or even normal operating voltage. The thermal effect generated by the strong power frequency fault current flowing through the porcelain insulator will often cause deterioration of the porcelain insulator. The iron cap exploded, causing serious accidents such as stringing of insulators and grounding of wires [1-3].

In recent years, the zero-value problem of porcelain insulators in newly commissioned and grid-connected operations has become increasingly prominent. Frequent occurrences of insulator explosions in transit have seriously threatened the safe and stable operation of the power grid. Take Hubei Company as an example. Since 2016, there has been at least one porcelain insulator bursting accident on the 110kV and above transmission lines of Hubei Company since 2016. For example, the 220kV Saitao line was struck by lightning in 2016 because the fault string has multiple (low) zero values. Insulators, lightning
flashover, fault current passes through the (low) zero-value insulator steel cap, causing the cement material inside the steel cap to rapidly heat up and expand and explode, and finally cause the insulator string to explode at the (low) zero-value insulator; In 2017, the entire string of insulators on 220kV Xiaomeng No. 2 circuit burst, and it was found that the deterioration rate of insulators on the faulty tower was as high as 39.73%. In 2018, there were three consecutive failures on the first and second lines of the 110kV E-Xia and Lihong lines, and the second line of E-Xia was in the substation. The string drop caused the ground turf to catch fire. The insulation resistance test of the replaced products of the same manufacturer and the same batch found that the deterioration rate was as high as 74.2%. The fundamental reason lies in the existence of low-zero-value insulators in the porcelain insulator string, and at the same time, the problem of inadequate daily inspection work for the low-zero value of porcelain insulators is exposed [4-7].

2. Model establishment

![Cross section of insulator](image)

The insulator used in this simulation experiment is mainly composed of four parts, namely iron cap, porcelain plate surface, cement glue and steel foot. Since the porcelain suspension insulator ignores the part of the iron cap that is used to install the plug, it can be considered It is an axisymmetric structure, so in order to reduce the amount of calculation, the simulation adopts a two-dimensional axisymmetric model, and only half of the insulator is modeled and simulated. The advantage of this is that it can greatly reduce the amount of calculation required for simulation and greatly shorten the calculation time. The cross section of the insulator is shown in Fig.1.

When doing multi-piece insulator simulation analysis, geometric modeling can be used to construct a cross-sectional model of the multi-piece insulator string in order to analyze the setting of boundary conditions.

During the simulation process, the simulation program scans and rotates the set two-dimensional cross section to obtain a complete three-dimensional model of the insulator string, as shown in Fig.2.
3. The influence of multiple zero-value insulators at different positions on the voltage distribution of insulator strings

In this simulation process, three adjacent zero-value insulators were selected and distributed on the conductor side, middle section, and grounding side of the insulator string, and simulated comparisons were performed respectively.

3.1. The second, third and fourth pieces are zero value insulators

To make it easier to analyze the results, compare the voltage distribution of insulators with zero value and the voltage distribution of normal insulator strings, as shown in Fig.3.

![Fig.3 Comparison of voltage distribution](image)

It can be clearly seen from Figure 5 that the voltage of the insulator around the zero-value insulator has increased compared to normal conditions, and the normal insulators farther from the zero-value insulator will be less affected.

3.2. The 13th, 14th and 15th pieces are zero value insulators

In order to facilitate the analysis of the results, compare the voltage distribution of insulators with zero value and the voltage distribution of normal insulator strings, as shown in Fig.4.
It can be clearly seen from Figure 4 that the voltage of the insulator around the zero-value insulator has increased compared to normal conditions, and the normal insulator that is farther from the zero-value insulator will be less affected.

3.3. The 25th, 26th, and 27th pieces are zero value insulators
In order to facilitate the analysis of the results, compare the voltage distribution of insulators with zero value and the voltage distribution of normal insulator strings, as shown in Fig.5.

It can be clearly seen from Figure 5 that the voltage of the insulator around the zero-value insulator has increased compared to normal conditions, and the normal insulators farther from the zero-value insulator will be less affected.

4. The influence of multiple zero-value insulators on the voltage distribution of insulator strings
In order to facilitate the analysis of the results, compare the voltage distribution of insulators with zero value and the voltage distribution of normal insulator strings, as shown in Fig.6.
It can be seen that when the number of zero-value insulators in the insulator string is large enough and the distribution positions are relatively diffuse, the voltage of the entire string of insulators in the insulator string will be higher overall.

5. Conclusion

If there are continuous multiple pieces of zero-value insulators in the insulator string, the voltage of the insulators around the zero-value insulators will increase compared to normal conditions, and the normal insulators farther from the zero-value insulators will be less affected.

If there are multiple consecutive zero-value insulators at different positions in the insulator string, if the number of zero-value insulators in the insulator string is large enough, and the distribution positions are more diffuse, the voltage of the entire string of insulators in the insulator string will be biased as a whole high.

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