Influence of Installation Mode of Sensing Board on Accuracy of Smart Voltage Measurement in Switch Cabinets

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Abstract. Based on the working principle of capacitor voltage transformer, this paper analyzes the influence of the installation mode of induced voltage board in the switchgear on the spatial stray capacitance by taking the switchgear, which is widely used as the carrier. Ansys finite element analysis software is used to establish the models of the voltage sensing board under different installation modes, and the influence of environmental factors such as the position, structure and temperature of the voltage sensing board on the stray capacitance between the bus bar and the sensing board is analyzed; The three-dimensional model of electric field shield plate structure is established for simulation. The installation mode of the voltage sensing board and the influence of the shielding board on the stray capacitance are revealed.

Keywords: Finite Element Model, Voltage Sensing Board, Stray Capacitance

1. Introduction
With the continuous development and improvement of the distribution network and the popularization and application of urban cables, the switchgear has become widely used switchgear because of its small size, complete function and low cost. Based on the higher requirements of power system for distribution automation, digitization and safety, electronic voltage transformer has gradually replaced the traditional electromagnetic induction voltage transformer and become the supporting equipment in the switch cabinet due to its small volume and high flexibility [1]. Due to the complex electric field inside the switchgear [2], the change of the installation mode of the voltage sensing board will have an impact on the stray capacitance. Therefore, it is very important to explore the influence of the installation mode of the voltage sensing board on the stray capacitance value, determine the best installation mode, and ensure the accurate measurement of the voltage transformer [3]. In addition, good shielding structure [4] can effectively shield and suppress the distributed capacitance in the switch cabinet, so that the three-phase voltage sensing board is in a uniform electric field.

For the accurate measurement of voltage transformer in switchgear, a lot of research results have been obtained. In [5], the influence of parameters on capacitor voltage transformer is studied, but the influence of stray capacitance in electric field is not fully considered. In [6], the effect of electric field on
the measurement error characteristics of capacitor voltage transformer is studied. In [7], it establishes the equivalent circuit model of distributed capacitance between voltage transformer and switch cabinet, analyzes the influence of distributed capacitance on the accuracy of voltage transformer, and puts forward the optimal design of shielding structure of voltage transformer. In addition, through the analysis of the partial discharge characteristics that may appear in the high-voltage switchgear [8], based on the capacitive coupling method, the partial discharge intelligent detection of the high-voltage switchgear [9] is realized, which can effectively detect the actual operation of electrical equipment.

This paper will establish a finite element model to analyze the stray capacitance in the switch cabinet, calculate the stray capacitance value in the switch cabinet when changing the installation position of the voltage sensing board, its own structure and environmental factors, and establish the shielding structure model of the voltage transformer to study the change of the stray capacitance value under the shielding structure.

2. System simulation model

2.1. Sic Structure of Switch Cabinet
The switch cabinet is mainly composed of bus room, handcart room, cable room and relay instrument room. In this study, the bus room of the switch cabinet is taken as the research object, and the structure of the switch cabinet is simplified: the main structure of the bus room is three-phase parallel bus bar.

2.2. Finite Element Model
Based on the basic structure of the switch cabinet, the voltage sensing board model is established. Its structure is shown in Fig.1, in which the left side of the cabinet is the bus bar A, B and C phases, and the right side is the voltage sensing board a, b and c phases. The bus bar and the sensing board are parallel and three-phase corresponding.

Considering the influence of the change of the distance between the sensing board and the bus bar on the stray capacitance value, the method of translating the sensing board can be used to calculate the capacitance value under different distances in turn.

Figure 1. Bus bar and sensing board model

Considering the influence of the change of the surface area of the sensing board on the stray capacitance value, the semi elliptical arc surface model as shown in Fig. 2(a) is established, and the surface area of the sensing board can be changed by changing the length of the minor axis of the semi ellipse. The height of the major axis of the semi ellipse is the same as that of the bus bar, which is 70mm. The minor axis takes 70mm as the benchmark and 10mm as the interval, which decreases in turn.

Considering the complex electric field interference in the switch cabinet, the shielding plate structure as shown in Fig. 2(b) is designed to effectively shield the electric field interference between adjacent phases and improve the efficiency of voltage transformer. According to the actual space size of the switch cabinet as a reference, the distance between the shielding plate and the sensing board is designed with 57.5mm as the benchmark and 10mm as the interval, decreasing in turn.
Based on Ansoft Maxwell 3D, according to the above conditions, select the electrostatic field to analyze the capacitance between bus bar A and sensing board a, b, c and set the voltage of bus bar, sensing board and shielding plate to 5775 V, 0V, 0V respectively.

3. Influence of Voltage Sensing Board Installation on Stray Capacitance
Stray capacitance refers to the space capacitance in the switchgear. Through the model analysis, it can be seen that the main factors affecting the stray capacitance value are the position of the voltage sensing board installation, the area of sensing board and the change of the temperature in the switchgear, other environmental factors will also have corresponding influence on the stray capacitance value. Considering the normal operation of the switchgear in different working conditions and different environments, this paper will focus on the influence of the installation mode of voltage sensing board on stray capacitance in the switchgear.

3.1. Influence of Position Change of Voltage Sensing Board on Stray Capacitance
Assuming that the external environmental factors of the switch cabinet are stable, the stray capacitance values of the voltage sensing board with different spacing are calculated when the voltage sensing board is installed parallel to the bus bar, and the results are plotted as a line chart as shown in Fig. 3. The abscissa represents the distance between the bus bar A and the sensing board a, and the ordinate represents the induced stray capacitance value.

![Figure 3. Capacitance variation caused by the change of the distance between the bus bar and the sensing board](image)

It can be seen that the variation of the distance between voltage sensing board and bus bar will cause the change of stray capacitance value. The variation trend is that the stray capacitance value between bus A and voltage sensing board a decreases with the increase of the distance between voltage sensing board and bus bar; and the stray capacitance between bus A and voltage sensing board b or c increases slightly.
3.2. Influence of Surface Area Change of Voltage Sensing Board on Stray Capacitance
Assuming that the external environmental factors remain unchanged, the parallel distance between the voltage sensing board and the bus bar is a fixed value. Change the surface area of the voltage sensing board, calculate the stray capacitance value, and draw a line chart as shown in Fig. 4. The abscissa represents the length of the minor axis of the elliptical surface, and the ordinate represents the stray capacitance value.

![Figure 4. Capacitance variation caused by surface area changes of sensing board](image)

It can be seen from the figure that the change of the surface area of the voltage sensing board will cause the change of the stray capacitance value. The change trend is that the stray capacitance value between the bus A and the voltage sensing board an increases with the increase of the surface area of the sensing board, and the stray capacitance value between the bus A and the voltage sensing board b or c also increases. However, with the increase of the area and the length of the short axis, the distance between the voltage sensing board and the bus increases, which will restrain the increase of the stray capacitance value. Therefore, the change of the stray capacitance value due to the change of the surface area is not obvious.

3.3. Influence of Temperature Change in Switch Cabinet on Stray Capacitance
Assuming that the structure shape of the voltage sensing board is unchanged and the relative position parallel to the bus bar is constant, the temperature of the switchgear in the environment is changed, the stray capacitance value is calculated, and the broken line diagram as shown in Fig. 5 is drawn. The abscissa is the temperature in the switchgear, and the ordinate is the stray capacitance value.

It can be seen from the figure that the change of temperature in the switch cabinet will cause the change of stray capacitance value. The change trend is that the stray capacitance value between bus A and voltage sensing board a increases with the increase of temperature; the stray capacitance value between bus A and voltage sensing board b or c has a slight increase trend.

4. Shielding structure parameters and installation position design
The installation of the shield structure reduces the interaction between the adjacent phase bus bar and the sensing board in the induction process and improves the stray capacitance value between the single-phase bus bar and the sensing board, which improves the accuracy of the single-phase induction results. Therefore, the installation of shield plate structure is necessary.

4.1. Influence of Shielding Plate Structure Parameters on Stray Capacitance
The influence of shielding material properties on stray capacitance is considered. Relative permittivity is a physical parameter that characterizes the dielectric properties or polarization properties of dielectric materials. The value is equal to the capacitance ratio of the capacitor with the same size made of the...
predicted material and the vacuum medium, which is also the characterization of the storage capacity of the material. Also known as relative permittivity. The relative permittivity of different materials is different at different temperatures.

Considering the influence of the thickness of the shield plate on the stray capacitance, based on the relative permittivity of the same material at the same temperature, a rectangular shield plate is horizontally installed between the three-phase bus bar and the phase of the voltage sensing plate. The thickness of the shield plate is changed, and the thickness of the shield plate is designed in the thickness range of 2mm-10mm with an interval of 2mm to calculate the spatial stray capacitance, draw a line chart as shown in Fig. 6.

![Figure 5. Diagram of capacitance change caused by temperature change](image1)

![Figure 6. Capacitance variation caused by thickness change of shielding plate](image2)

It can be seen from the figure that the change of the thickness of the shielding plate will cause the change of the stray capacitance value, but the change range is small. The change trend is that the stray
capacitance value between bus A and voltage sensing board a decreases with the increase of the thickness of the shielding plate; The stray capacitance value between the busbar A and the voltage sensing board b or c also shows a decreasing trend. So in order to improve the accuracy of intelligent voltage measurement, it is not suitable to choose the thick shield plate.

4.2. Influence of Shield Installation Position on Stray Capacitance
Considering the influence of the installation position of the shield plate on the stray capacitance value, select the appropriate thickness and material of the shield plate. Design the shield plate structure shown in Fig. 2 (b). According to the actual space size of the switch cabinet, design the space between the induction board and the shield plate within the interval of 17.5mm-57.5mm with the interval of 10 mm, calculate the space stray capacitance value, and study the optimal position of the shield plate structure installation. Draw a line chart as shown in Fig. 7.

It can be seen from the figure that the installation of the shielding board makes the stray capacitance value induced between the bus A and the voltage sensing board a increase significantly, but with the increase of the distance between the shielding plate and the sensing board, the increase amplitude of the capacitance value is gradually gentle; at the same time, the stray capacitance value between the bus A and the voltage sensing board b increases, but the increase is small; the stray capacitance value between the bus A and the voltage sensing board c decreases gradually until it is almost zero, so the switch is considered. Under the condition of large cabinet space, the electric field interference in the switch cabinet can be effectively shielded by selecting the appropriate location to install the shielding board.

![Figure 7. Capacitance variation caused by distance change between shielding plate and sensing board](image)

5. Conclusion
Based on the complex electric field in the switch, it is very important to design the installation mode of voltage sensing board to realize intelligent voltage measurement. In this paper, the attribute parameters of the research object are analyzed, and the finite element model of stray capacitance calculation in the switch cabinet is established.
Aiming at the research problem, a finite element model is established for simulation, focusing on calculating the influence of the surface area, distance from the bus bar, temperature and other factors on stray capacitance. Specifically, the surface area and distance of the sensing board are the main factors affecting the spatial stray capacitance. The stray capacitance value increases with the increase of the surface area and decreases with the increase of the distance. By establishing the shielding plate model, it can be seen that the shielding structure can effectively shield the electric field interference in the switch cabinet and improve the efficiency of voltage mutual inductance.

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