LIGHTING IMPULSE DISCHARGE CHARACTERISTIC OF COMPOSITE INSULATOR DEVELOPED FOR APPLYING IN 3500M ALTITUDE

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ABSTRACT

With the development of power industries, in recent years, more and more switchgears used in high altitude were needed in China market. At the region of higher altitude, due to the lower air density, the insulation strength of air sharply decreases, so external insulation design of electrical equipment used in high altitude regions is a critical factor.

In this paper, a new post insulator applied in 3500m altitude was developed, design test results shows that this new insulator did not satisfy with requirements of high altitude application. For improving the product performance, electrical field simulations were implemented to optimize the design of new insulator. Based on these simulation results, we can find two different improvement methods:
1) Modify the shed structures of new post insulator.
2) Change the design of high voltage inserts involved in post insulator. Verification test results can prove that two improvement methods can effectively increase the insulation capacity of insulator.

1. INTRODUCTION

In recent years, with the development of social economic and power grid, more and more switchgears used in high altitude were needed in China market. At the region of higher altitude, due to the lower air density, the insulation strength of air sharply decreases, so external insulation design of electrical equipment used in high altitude regions is an important design consideration.

According to the requirement of GB 11022-2011and IEC62271-2007, for those installations used at an altitude higher than 1000m, the insulation capacity of electrical equipment needs to be increased. In this paper, a new post insulator applied in 3500m altitude was developed, design test results shows that this new insulator did not satisfy with requirements of high altitude application. Test results of electrical performance (partial discharge (PD), power frequency withstand voltage (PFWV) and lighting impulse (LI)) show that PD and PFWV can pass the design tests, but real LI performance(246kV) of this new post insulator is lower than the requirement of 254kV(1.37 × 185kV).

For improving the product performance, electrical field simulations were implemented to optimize the design of new insulator. Based on these simulation results, we can find two different improvement methods:1) modify the shed structures of new post insulator, 2) change the design of high voltage inserts involved in post insulator. Verification test results can prove that two improvement methods can effectively increase the insulation capacity of insulator.

2. PRODUCT DESIGN AND SPECIFICATION

Based on the requirement of standard GB and IEC, the insulation withstand level of external insulation at the service location shall be determined by multiplying the rated insulation levels with a factor Ka in accordance with following modification equation:

$$K_a = e^{(H-1000)/8150}$$

For those switchgears and insulation components of 40.5kV voltage rating, the insulation withstand levels should be 95kV and 185kV for Power frequency and lighting impulse respectively under 1000m altitude. Moreover, in the standard of DL404-2007, the minimum value of 300mm air clearance of phase to phase and phase to ground was required to assure the basic insulation performance of 40.5kV switchgear. So, for satisfying the requirement of application in 3500m altitude, the minimum value of air clearance was required for the application of 3500m altitude is:

$$K_a = e^{\frac{3500-1000}{8150}} = 1.37$$

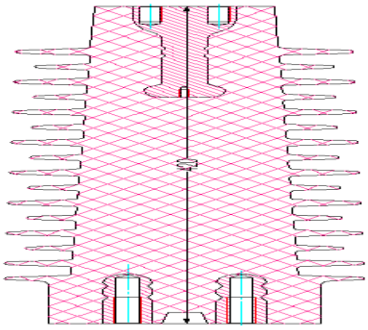
Real design value of height of insulator is 420 mm, this design value is greater than that value present by standards. So, based on the requirements of the application environment, detail design specification of 3500m can be summarized as following Table1. Designed drawing and product example were showed in Fig.1

Table.1 Product Specifications

Rating Voltage(kV)	Rating Current(A)	Altitude(m)	Power Frequency Withstand Voltage	Lighting Impulse	Relative Humidity	Inception Voltage of Partial Discharge(kV)	
40.5	1250	3500	130	254	95%	42	

Table 2 design test results of electrical insulation performance.

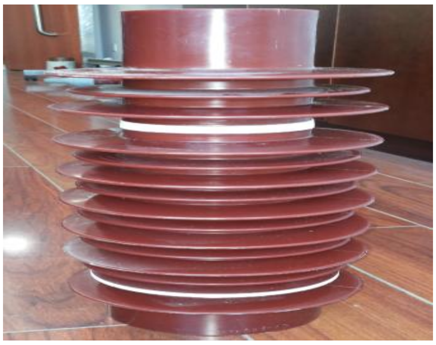
Parameters	Power frequency withstand voltage(kV)	Lighting impulse withstand voltage(kV)	Inception voltage of partial discharge(kV)
Standard Value	130	254	42
Test Value	138	246	70



(a)Outline drawing of post insulator

(b) Product picture

Fig.1 Outline drawing and product picture of composite insulator developed for applying in 3500m altitude.



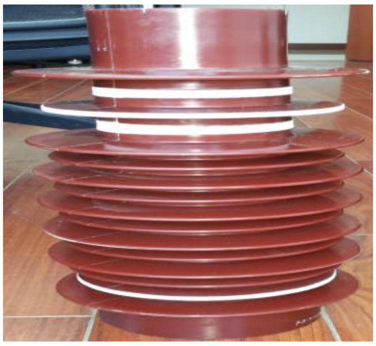


Fig.2 Pictures of modified insulator

3. DESIGN TESTS, PRODUCT MODIFICATION AND SIMULATIONS

According to the product specification and requirements of GB, DL and IEC standards, design tests were completed on the product example showed in Fig 1(b), the electrical insulation performance of this new post insulator must satisfy the technique parameters given in Table 1. Design tests results can be found from following Table 2.

From Table2 above, we can know that the new product does not satisfy the specified value by standard GB and DL. Lighting impulse withstand voltage is lower than that value specified in standard.

Based on the test results and product structure, at the same time, we can apply simulation to find the features of electrical field, critical sheds which influences heavily the electron drift were cut. Modified product pictures were present in Fig 2. Verification test implemented on modified insulator, test results were given in Table3.

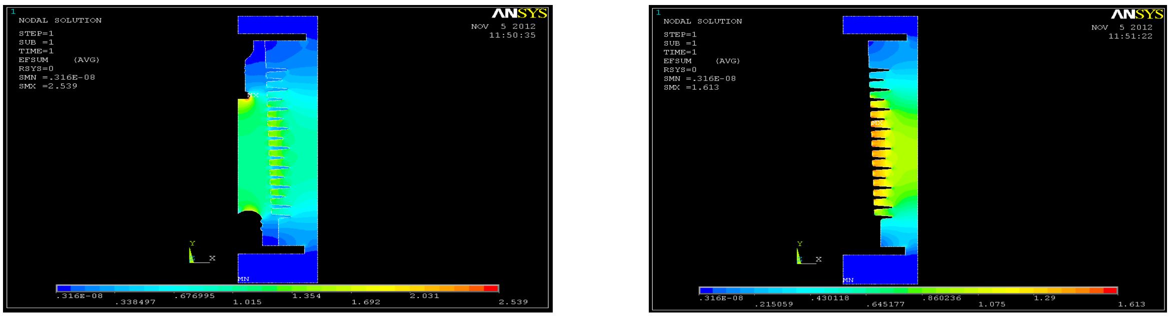
See from the verification test results showed in Tabel3, we can know that the power frequency withstand voltage and lighting impulse withstand voltage both can comply with the product specification. Only the inception voltage of partial discharge is lower than that value determined by standard, the root cause is due to that the surface condition of modified insulator occurs change by machining.

Electrical field simulations were completed for find out the characteristic of electrical

field distribution of insulator. Simulation results were showed in Fig.4, Fig 4 (a) and

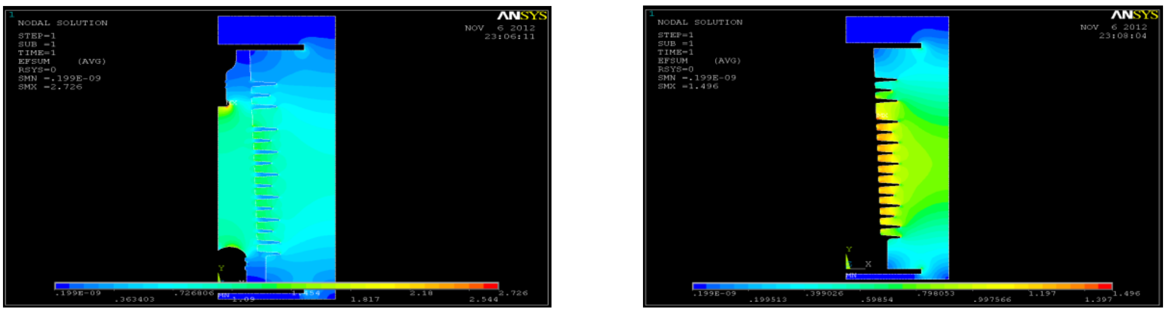
Table3 Verification test results after cutting the shed of insulator.

Parameters	Power frequency withstand voltage(kV)	Lighting impulse withstand voltage(kV)	Inception volate of partial discharge(kV)
Standarded Value	130	254	42
Test Value	140	272	56



(a) Electrical field distribution in whole solved region ***(b) Electrical field distribution of air around insulator***

Fig. 3 Distribution of electrical field of old design



(a) ***(b)***

Fig. 4 Distribution of electrical field of insulator with cut shed.
(a)electrical field distribution in whole solved region after cutting shed
(b) electrical field distribution of air around insulator with cutting shed

(b) give the distribution of electrical field of original design, Fig 4(c) and (d) show simulation results on modification insulator.

4. DESIGN IMPROVEMENT AND SIMULATIONS

We can know from design test results mentioned above that poor design of shed will heavily decrease the electrical insulation performance of post insulator. As known in mind, the filling processing and design will change sharply electrical field distribution around metal insert of high voltage and grounded.

Verification test results show improvement design of high voltage inserts can increase effectively the insulation performance of insulator. See from Table 4, lighting impulse withstand voltage with small marge comparing to the value specified by standard. Therefore, we can know that a bigger filling of high voltage insert can reduce the maximum value of electrical field. Filling outlines of high voltage insert were showed in Fig.5.

5. CONCLUSIONS

Under the condition of high altitude, due to that air density decreases gradually with raising of the elevation, the exterior insulation capacity of electrical device and equipments declines. Through the development of a new post insulator used at the altitude of 3500, we can figure some important conclusions:

- Shed structures influence heavily the insulation performance of post insulator. And more sheds do not mean higher insulation performance.
- Modification of shed structure and filling of high voltage insert end can effectively improve insulation capacity of post insulator.
- Electrical field simulation is an important tool used to develop new products.

Table 4 Verification test results after improving.

Parameters	Power frequency withstand voltage(kV)	Lighting impulse withstand voltage(kV)	Inception voltage of partial discharge(kV)
Standard Value	130	254	42
Test Value	146	258	76

(a) Original design of high voltage insert ***(b) Improved filling of high voltage insert***

Fig. 5 High voltage insert used in inulator

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