

# OVERVIEW ON GAS DISCHARGE OCCURRING IN AIR INSULATED METAL ENCLOSED SWITCHGEAR

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## ABSTRACT

Compact 40.5kV air insulated metal enclosed switchgear with VCB is mostly used in power substation of 220kV and industry consumer with heavy loads. Practical operation of many years has proven that many faults had occurred in 40.5kV air insulated metal enclosed switchgear. Statistic data shows the most fault and failure is resulted from the poor insulation performance. Moreover, different discharge type will occur in the same insulation component used in different operation conditions of switchgear.

In this paper, the most common insulation components of spout and bushing used in air insulated metal enclosed switchgear were reviewed on faults and failures. Specially, simulation was implemented on the typical fault occurring in bushing, simulation results show that simulation is a useful tool used to analysing the defects of product design and manufacturing process.

## 1. INTRODUCTION

In recent years, Due to the advantage of compact design, lower cost, convenient operation and maintenance-free, air insulated metal enclosed switchgears were used widely in the medium voltage rating of electrical distribution system of

power grid and industries application. Comparing to the old design of air insulated metal enclosed switchgear, some main changes exist in the new air insulated metal enclosed switchgear: smaller dimension, withdrawal VCB (Vacuum Circuit Breaker) with trolley, three functional compartments separated by metal partitions. For these new improvements, the new products of air insulated metal enclosed switchgears possess good market shares. Specially, in China market, this product still increase by 20% per years in recent 5-8 year.

Experience of operation in field shows that operation performance of air insulated metal enclosed switchgear is poor compare to the old product: the width of switchgear is greater than 1.6m. Moreover, the insulation fault occurs frequently.

In this paper, many fault types occurring in air insulated metal enclosed switchgear were clarified based on the root causes of insulation faults. At the same time, analysis and simulation were implemented for verify the fault types.

## 2. INSULATION FAULT AND ANALYSIS ON BUSHING

### 2.1 Fault types and analysis

Bushing is one of the most key insulation parts used in the air insulated metal enclosed

switchgears, Electrical field distribution of bushing is the most important design factor, therefore, for improving the insulation performance of insulation components, electrical calculation and simulation would be keep in the mind of product engineer.

As showed below Figure 1, different fault and failures will appear in the operation field of bushing. Of course, these faults would be caused by different root causes. Operation experience shows that main fault and failure types commonly include: 1) Irrational product design (not outlined in this paper), 2) Manufacturing process of product is out of control, 3) Severe service condition, 4) Incorrect product assembly.

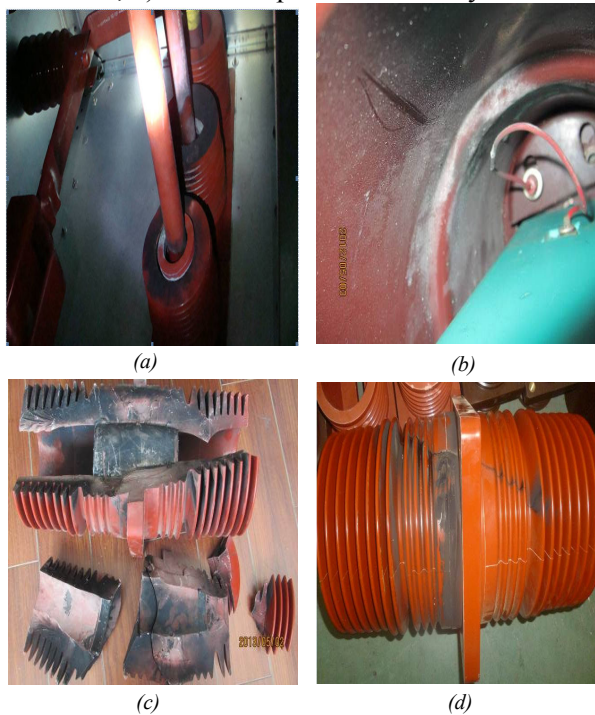


Fig. 1 Different air discharge appearances occurring in bushing.

### 2.1.1 Incorrect product assembly

See from Fig.1 (a) below, we can know that root cause of this fault occurring between two phases of bushing is incorrect product assembly: insulation support plate is not safely fixed with busbar and bushing, due to the wrong assembly, electrical field distribution around busbar inside bushing can change sharply. Consequently, partial discharge will exist around busbar inside

bushing. Therefore, insulation material nears the location of partial discharge will be gradually aged. At the same times, high electrical stress will appear around the aged insulation material. With the further development of partial discharge, insulation performance of bushing becomes more deterioration. Finally, single phase partial discharge transfers to the flashover appearing among two phase bushing.

### 2.1.2 Severe contamination

As showed in Fig.1 (b) below, partial discharge occurs inside bushing, the root cause resulting in the partial discharge is the severe contamination inside bushing. Specially, connection wire between busbar and bushing touches nearly with the interior surface of bushing. Under the influence of severe contamination, partial discharge arises near interior wall of bushing and connection wire, with the continuous development of partial discharge, the insulations performance of bushing will degrade. Finally, the insulation faults appear as that showed following figures.

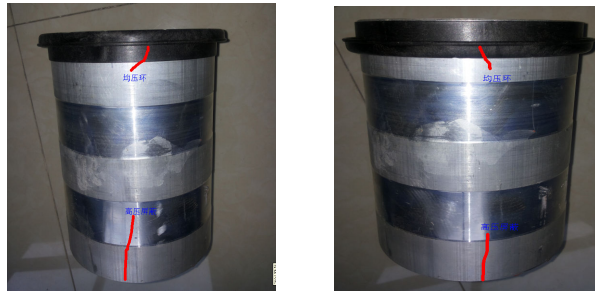
### 2.1.3 Out of control in manufacture processing of bushing.

We can know from Fig.1(c) and (d), the interior insulation fault occurs between high voltage ring and grounded ring used to grading the electrical field. The cause leading to the insulation failures is wrong assembly before casting, this wrong results in the higher electrical field strength in critical position of bushing. Corrent and wrong assembly pictures of grading ring were showed in Fig2(a) and (b).

### 2.2 Electrical simulation on failure bushing

In this paper, simulations of electrical field were completed for analysing two different assembly of grading ring. Simulation results were present in Fig2(c) and (d). we can know from simulation results showed below that the electrical field strength of critical position of wrong assembly bushing is obviously higher than that of correct

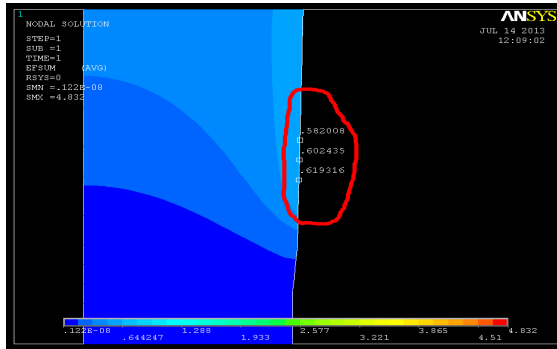
assembly bushing.



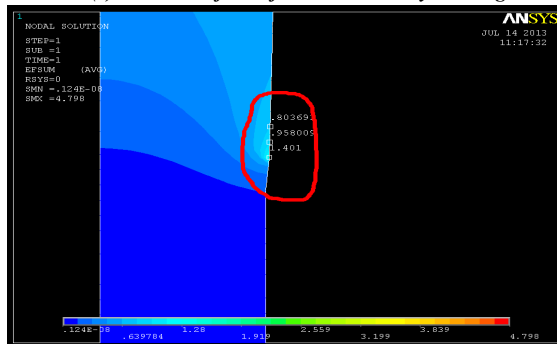
(a) (b)

(a) Correct assembly of grading ring

(b) Wrong assembly of grading ring



(c) Electrician field of correct assembly bushing



(d) Electrician field of wrongt assembly bushing

Fig. 2 Electrical Field Simulation on Key Position of Bushing.

### 3. INSULATION FAULT AND ANALYSIS ON SPOUT

#### 3.1 Fault type and analysis

##### 3.1.1 Poor design

Normally, some common insulation faults will occur in service field of spout used in air insulation metal enclosed switchgear, some fault types were present as following Fig.3.

In practice application, for mitigating corona discharge of static contact installed inside spout, grading ring was frequently applied to improve

electrical field distribution around the end of static contact. Fig3 (a) shows an example of grading ring. Though the design can improve the partial performance of the end of fixed contact inside spout, but there is a pitfall of electrical field which exists between phase and phase, therefore, the electrical stress of the gap between phase and phase will sharply rise, the distribution of electrical field had change comparing to that when there is not grading ring embedded in spout. Under the influence of the severe operation environment: high humidity and heavy pollution. Air discharge of gap between phase and phase will occur. Partial discharge will lead the aging of epoxy resin of spout. Consequently, the aging result in the poor insulation performance of spout, with the future development of partial discharge and aging, finally, the fault of short circuit will lead to the failure of insulation performance of spout.



(a)

(b)



(c)

(d)

Fig. 3 Air discharge appearing in spout

##### 3.1.2 Poor manufacturing and assemble processing.

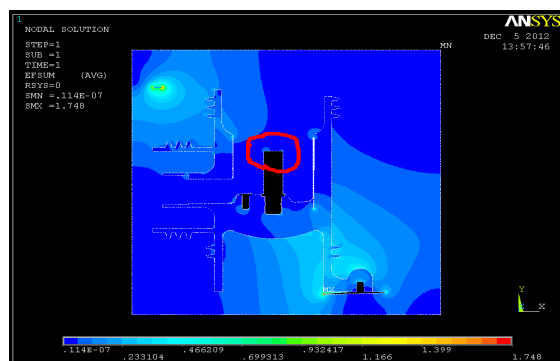
It is very important to keep in mind for a product designer that metal shape is easy to lead to corona

discharge. Eventually, it is possible to result in the insulation failure and insulation aging. As showed in Fig3(c), the sharp end of busbar inside spout leads to partial discharge.

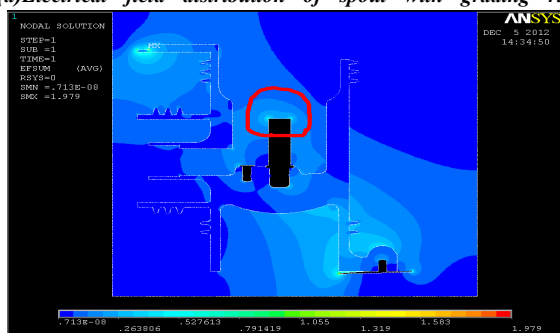
Good product and design maybe also be possible to lead to insulation faults, the root cause is incorrect product assembly in the workshop, the real fault picture as showed in the Fig3 (d).

### 3.2 Simulation on Spout

Based on the description present in 3.1, some simulations were implemented on spout with grading ring and without grading ring, simulation results were showed Fig4. We can find two figures from the simulation results as following: 1) corona discharge of fixed contact used in spout with grading ring can be successfully be eliminated, 2) at the same time, electrical field distribution among gap between two phase spouts changes sharply.



(a)Electrical field distribution of spout with grading ring



(b) Electrical field distribution of spout without grading ring

Fig. 4 Electrical Field distribution of spout

## 4. CONCLUSIONS

Different faults and failures occurring in

operating air insulated metal enclosed switchgear were summarized, at the same time, comparing the failure mode of critical insulation parts with simulation results, some important conclusions can be found as follow:

- (1) Insulation design is very important to
- (2) Manufacturing process of components used in switchgear panel also heavily influences the insulation performance of switchgear.
- (3) Simulation is a useful tool to improve and prove the product performance.

For improve the insulation performance of air insulated metal enclosed switchgear, some FEA simulation and electrical tests were implemented in this paper(shown in Figure2 and Figure4), practical test proven that it is feasible to apply these simulation results to explain the root cause of failures.

## REFERENCES

- [1] S. Sato, M. Sawada, K. Koyama, T. Itotani, et al. Relationship between surface flashover voltage and electric field strength at earthed triple junction in vacuum. Pm. of the meeting Electrical Discharges, IEEJ, SPb1-90, pp.13-18, Dec. ZwO (in Japanese).
- [2] W Lord, L Larsson. Economical Differences in Using Modified 36-40.5 kV Equipment. Vattenfall Power Consultant AB Report, 2006, (Only in Swedish).
- [3] Joie Pihler, Igor TiEar, Joie VorSiE. Epoxy Bushing Used in Medium Voltage Switchgear. 1998 International Confemce on Conduction and Breakdown in Sdid Didxtrks, June 2225,m V- Sweden, pp.506-509.
- [4]. Hongmei Li, Dongxian Tan, Yuhua Liu, Application Condition of 40.5kV Air Insulated Metal Enclosed Switchgear with VCB in China, CISED, 5<sup>th</sup> International Conference on Electricity Distribution, Shanghai, 5-6 Sept 2012.