THE DEVELOPMENT OF 25.8KV CLASS SOLID INSULATED SWITCHGEAR

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ABSTRACT

In recent years, the companies of electric power equipments for MV and HV class trend to develop the ecofriendly insulated switchgear which replaces existent SF6 gas insulated switchgear due to environmental problems such as global warming and so on. This paper makes reference to the newly developed Solid Insulated Switchgear (SIS) which uses the ecofriendly material such as epoxy for insulation. The insulation material of the Solid Insulated switchgear (SIS) is composed of an epoxy, vacuum and air. The Solid Insulated Switchgear (SIS) is a state of the art product. In the product(SIS), there are a lot of advantages such as advanced reliability, safety, economical efficiency, maintenance free, reduction of installation area and the protection of environment. This paper is intended to introduce characteristics for a newly developed Solid Insulated Switchgear (SIS).

Ⅰ INTRODUCTION

At the power equipment industry, SF6 gas is useful insulation material because it has superior characteristics, performances of electrical insulation and arc extinguishment for MV (Medium Voltage), HV (High Voltage) classes. [1~3] However, this SF6 gas entitled a greenhouse gas(CO2, N2O, CH4, PFCs, HFCs, SF6) that is the principal factor of global warming according to Kyoto's protocol in 1997 years. The greenhouse gas must be reduced compulsorily from advanced nation of Europe from 2008. [4] Also, the RoHS(Restricting the use of Hazardous Substances) took effect in July 2006. This agreement is mandatory so that the party to the agreement can not use noxious material which is harmful to human in electrical, electronic components. [5] Effort to make ecofriendly product in power equipment company is continued by several factors such as environmental restriction.[6~7]

A Solid Insulated Switchgear(SIS) has the following major characteristics.

1. Reliability and economical efficiency
   - Test duty depend on international standard
   - Construction cost reduce owing to compact size
     (W : 600mm, H : 1850mm D : 1450mm)
   - The composition of single and double line are easily realized
2. Safety and maintenance free

   - The surface of all module get to a metallic treatment
   - Apply to a high reliability mechanism
3. Eco-friendly instrument
   - Greenhouse gas free and Epoxy material used

Ⅱ DESIGN AND CONSTRUCTION

The newly developed Solid Insulated Switchgear (SIS) consists of four parts which are DS/ES part, CB part and Incoming part. Each of parts has characteristic that is connected each part.

Fig. 1 shows the construction of SIS

![Diagram of SIS](image)

(1) DS Part    (2) ES Part
(3) CB Part    (4) Incoming Part

Fig. 1 The construction of SIS(Double Bus type)

(1) DS(Disconnecting Switch) part
- DS part of SIS adopts DRS(Double Rod Sliding) switching method. This method operating principle is similar to the operating structure of general rod(pole) antenna. Disconnecting Switch(DS) is operated by motor-charging mechanism.
- We design a shaft housing that can both insulate by electric and operate ON/OFF by mechanical rotating inside the epoxy.

(2) ES(Earthing Switch) Part
- This part operates by DRS method and adopts mechanism similar to DS part too. And it has different structure with compared to ES as shown in figure 1-(2).
(3) CB(Circuit Breaker) Part
CB Part is the most important fact in Solid Insulated Switchgear(SIS). CB part is consisted of Embedded VI and PMA(Permanent Magnetic Actuator) mechanism. A permanent magnetic actuator (PMA) is linked to Embedded VI. An Adopted PMA mechanism to CB part can been modified commercially.

(4) Incomming Part
Incomming Part is consisted of LA(Lighting Arrester) Socket Mold(DIN47637 Plug in type, Size 1) and Cable Socket Mold(Size 3). This part is connected to voltage of distribution class. The Cable Socket Mold adjusted to current capacity.

All of parts are connected to each other. Flexible assembly system is priority strong merit.
The number of CAE tools such as 3D CAD (Pro Engineering), Electromagnetic simulation analysis (Maxwell), Mechanical stress analysis (Mechanica Pro), Thermal distribution and fluid simulation (Fluent), etc., were used for optimal design.

Fig. 2 Electromagnetic analysis of Embedded VI for SIS
Fig. 2 and Fig. 3 shows performing example for ideal design.

(a) CB shaft lever
(Ultimate stress: 6.685x10^4 kg/sec^2 mm, Yield stress: 2.1x10^5 kg/sec^2 mm)

(b) epoxy mold
(distribution load of interface: 100kg/mm^2, boundary condition: fix the insert hole)

Fig. 3 The analysis of mechanical stress for SIS

III. INSULATION MATERIAL
A basic insulation medium of SIS is air and epoxy. There is not SF6 gas.
The major part which uses epoxy resin is the core component of SIS
The comparison of the specification between conventional epoxy resin and that of SIS is shown in Table 2.
Table 2 shows the epoxy applied for SIS which has very stable property That’s because Tg point rises over about 30 ℃ than existing epoxy. Tg point is changed of molecular structure of epoxy, and influences a stress, embrittment and electrical property and etc. Also, crack by adhesion or temperature variation of another material decreased remarkably because a coefficient of thermal expansion is very low. Besides, SIS strengthens reliability for epoxy with increase of a tensile and flexural strength.

Table. 2 The comparison of epoxy property

<table>
<thead>
<tr>
<th>Property</th>
<th>Epoxy</th>
<th>Conventional type</th>
<th>Applied type for SIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tg[°C]</td>
<td></td>
<td>100-110[°C]</td>
<td>140-146[°C]</td>
</tr>
<tr>
<td>Coefficient of linear thermal expansion (Mean value [°C]</td>
<td>K-1[°C]</td>
<td>36-40 x 10^-5[°C]</td>
<td>17 x 10^-5[°C]</td>
</tr>
<tr>
<td>Flexural strength [N/mm²]</td>
<td></td>
<td>120-130[N/mm²]</td>
<td>150-160[N/mm²]</td>
</tr>
<tr>
<td>Tensile strength [N/mm²]</td>
<td></td>
<td>75-85[N/mm²]</td>
<td>90-100[N/mm²]</td>
</tr>
<tr>
<td>Dielectric constant [°C]</td>
<td></td>
<td>3-4[°C]</td>
<td>3.8[°C]</td>
</tr>
</tbody>
</table>

Additionally, it enables the VI(Vacuum Interrupters) to be cast directly. Vacuum interrupter is encapsulated with epoxy for external insulation. The epoxy embedded vacuum interrupter(Embedded VI)
is a crucial technology for solid insulated switchgear (SIS).

**IV. ACTUAL TEST AND VERIFICATION**

SIS duty test has been verified by international standard (IEC 60694, 62271-100/200, etc.) test. [8]

The rating by this standard is shown in below Table 1.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Rated voltage</td>
<td>25.8 kV&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated current</td>
<td>630, 1250, 2000 A&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>60 Hz&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated Power Frequency withstand voltage</td>
<td>- Common value : 70kV/1min&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>- Across the isolating distance : 77kV/1min&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated Lighting Impulse withstand voltage</td>
<td>- Common value : 150kV BIL&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td></td>
<td>- Across the isolating distance : 165kV BIL&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Partial Discharge (PD)</td>
<td>Below 10pC to 1.1Ur/3&lt;sub&gt;e&lt;/sub&gt;, 3phase simultaneously&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated short-time withstand current</td>
<td>25 kA/3sec&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Rated peak withstand current</td>
<td>65 kA peak&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
<tr>
<td>Degrees of protection</td>
<td>IP4X&lt;sub&gt;e&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Table 1. The rating for SIS

Also, all parts of SIS carried out a number of tests. The performed tests are mechanical stress test, partial discharge test, x-ray test, EMC test for CB part controller unit, tensil test and so on. Generally, the mechanism of circuit breaker (MV Class – 24kV 25kA) must be satisfied with operating speed up to both 1.1m/s(close) and 0.9m/s(open).

The newly developed SIS has sufficient operating speed to when close and open.

![Operating graph of CB part](image1)

Fig. 4 Operating graph of CB part

For Last of verification, SIS had been established to actually working site on our factory. (LS industrial systems Ltd.)

The SIS was installed for test on the factory’s substation. It is consisted of Main, PT and Feeder Panel.

![Established SIS on our factory's substation](image2)

Fig. 5 Installed SIS on the our factory’s substation

**V. CONCLUSION**

Since ecofriendly power equipments are required, we have developed the power equipment (SIS). The newly developed equipment is called Solid Insulated Switchgear (SIS).

When designing, we have performed a lot of Computer aided simulations. A number of trial and error tests were performed for integrity of SIS.

Finally, for the verification of SIS capability we performed international standard (IEC 60694, 62271_100/200, etc.) tests.

As a result of test, the solid insulated switchgear (SIS) has been estimated as an alternative for eco-friendly MV class switchgear.

REFERENCES