Indonesia Corner
Mitigation of Ceramic Outdoor Insulator Failures in Indonesia

1. Introduction.
Indonesia is a tropical country which is situated around the equator. The sun is overhead in the country throughout the year. Temperature in Indonesia is usually high. Maximum temperatures are 30-34°C at sea level and 27-31°C at 500 m. The typical minimum temperatures are 20 to 25°C at sea level and 17 to 22°C at 500 m[1].

There are 2 seasons, rainy season and dry season. During rainy season, the rainfall usually high and during dry season low. Irian Jaya is the highest rainfall area with mean annual rainfall of up to 3185 mm. Java and Madura as the most populous area have mean annual rainfall of 2571 mm. Due to high rainfall, the relative humidity (RH) in most of Indonesian parts is high. During night and early morning, the RH is as high as 95%. The high values of rainfall and humidity easily cause corrosion.

Since the sunshine is bright throughout the year, the solar radiation is high in Indonesia. The typical value of the solar radiation is 1.250 W/m². This high solar radiation contributes to the acceleration of aging of electrical apparatuses especially outdoor high voltage equipments.

In Indonesian electric power lines 500 kV, 275 kV, 150 kV and 70 kV voltage levels are being used in transmission lines while 20 kV and 220/380 V are used in distribution lines. 500 kV EHV lines are being used as the back bone of electric power transmission in Java Island which is at present composed of 15 EHV substation and 1,565 km EHV transmission lines. The 275 kV networks are being used in Sumatra. In the near future, the 275 kV lines will be expanded in Sumatra and 500 kV transmissions will also be introduced[2]. System failure due to insulator problems is high in Indonesia. To keep the systems in good operational condition, reliability of outdoor insulators is important.

2. Outdoor Insulator Failure
Outdoor insulators are exposed to environmental climate such as high temperature and humidity as well as pollution from coast and industries. As the result, leakage current may flow on the insulator surface and may degrade the insulator surface[3]. Under particular condition, dry band arcing may take place on the insulator surface leading to the failure of the insulators[4]. There are 2 kinds of failure modes widely found in Indonesia. They are flash over due to lack of ability of the insulator surface to withstand the applied voltage and mechanical failure due to corrosion. Corona generates UV light, heat, electromagnetic radiation and gaseous by products such as ozone and nitrogen oxides. The last gas may be converted to nitric acid under a particular circumstances which may corrode the pin part of an outdoor insulator.

Examples of the two failures are shown in figure 1. Figure 2 shown a large number of fail insulators taken from services.

3. Efforts to mitigate insulator failures in Indonesia
There are three solutions introduced to solve the environmental problem on the insulator surface. They are improvement of insulator design, periodic washing, and coating with water-repellent agents or other surface treatments.

3.1 Application of fog type insulators and increasing the number of insulator string
It is common in Indonesia to use fog type insulators or additional insulator string in highly polluted areas.

3.2 Periodical insulator washing
This method mainly applied for substation located at heavily polluted areas. This method is effective to mitigate insulator failures, however costly and labour ineffective.

3.3 Application Semiconducting Glazed Insulator (SCG)
In 2004 more than 40,000 pieces of semi-conducting Glazed (SCG) insulators were installed to overcome high insulator failure rate at 150 kV lines in Southern Coastal area of East Java Island such as Jember, Banyuwangi, Lumajang. The insulators were also installed in Bali Island such in Kapal, Gianyar, Sanur, Nusa Dua, Gilimanuk and Pesanggaran. The semiconductor glaze used was tin-oxide. At the beginning of the operation, the insulators performed very well. The failure rate decreased drastically. However, after 3 years of operation many failures took place. Large number of insulator string were broken, damages and flashover as shown in figure 4. Finally, in 2007 all the SCG insulators were removed from system (figure 5) and replaced by conventional ceramic insulators. It was concluded that application of SCG in Indonesian coastal area like East Java and Bali is not suitable[5].

### 3.4 Silicone coating

In effort to mitigate insulator failures, silicone coating application was considered. There were 3 kinds of insulators used in the experiment. The first insulator was 20 kV class pin-post type ceramic insulators. The insulators are widely used in Indonesian State Electricity Corporation (PT. PLN) network. The second insulator was suspension type with creepage distance of 315 mm. The insulators are widely used for 500 kV transmission line insulator strings. The typical silicone coated insulators are shown in figure 6. The trial application of these type silicone coated insulators were conducted at Pangandaran substation which is located at coastal area about 500 m from Indonesian Ocean southern of Java Island.

The last sample was rod type insulator used at 150 kV transmission as shown in figure 8. The rod type insulators were installed in 150 kV transmission lines...
at Ketewel coastal area in Bali Island[6]. This area is a heavily coastal polluted and many insulator flashovers are found.

The silicone coated rod type insulator was installed in 2009 and so far performing very well.

**Corona suppression**

The corona intensity measured by using a UV camera Daycor II SN 169 from coated insulator was as low as 10% of uncoated insulator as shown in figure 9.

![Corona intensity measurement](image)

Figure 9  Corona intensity at uncoated (a), (b) and coated (c) insulators measured using UV Camera

The application of silicone coating also reduced the insulator temperature. Figure 10 shows the thermal image of uncoated and coated insulators taken using FLIR IR camera.

![Thermal image comparison](image)

Figure 10  Thermal image of insulator (a) phase S (uncoated) and (b) phase T (coated)

**Leakage current suppression and flashover voltage increase**

The leakage current flowed on the insulator surface was measured by measuring the voltage across a series resistance using a Digital Oscilloscope with digitizer of 8 bit, bandwidth of 100 MHz, and the maximum sampling rate of 1 GS/s.

Table 1 shows the typical leakage current on non coated and RTV coated suspension insulators as function of applied voltage under kaolin salt pollution at 40 mS/cm. The table indicates that RTV coating reduces the leakage current significantly. The table also shows that non coated insulator flashover at applied voltage of 35 kV. However, no flashover was observed for RTV coated insulators even at applied voltage of 45 kV. The leakage current was also as low as 0.8 mA at this voltage level. The facts indicates that RTV coating on insulator surface greatly increases the flashover voltage. Therefore, mitigation of insulator flashovers can be done using RTV coating.

<table>
<thead>
<tr>
<th>Voltage (kV)</th>
<th>Leakage Current (mA) Non-coated</th>
<th>Leakage Current (mA) RTV Coated</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.226</td>
<td>0.073</td>
</tr>
<tr>
<td>10</td>
<td>0.358</td>
<td>0.151</td>
</tr>
<tr>
<td>15</td>
<td>0.371</td>
<td>0.224</td>
</tr>
<tr>
<td>20</td>
<td>0.695</td>
<td>0.305</td>
</tr>
<tr>
<td>25</td>
<td>1.601</td>
<td>0.394</td>
</tr>
<tr>
<td>30</td>
<td>-</td>
<td>0.478</td>
</tr>
<tr>
<td>35</td>
<td>Flash Over</td>
<td>0.580</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>0.705</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>0.811</td>
</tr>
</tbody>
</table>

**Hydrophobicity Improvement**

Good outdoor insulators have a strong ability to repel water and pollution from their surfaces. This property is called as Hydrophobicity. Hydrophobicity is indicated by its contact angle. The silicone coated insulators are more hydrophobic as shown in table 2.

Table 2 Contact angle for coated and uncoated insulators

<table>
<thead>
<tr>
<th>No</th>
<th>Water Droplet Profile</th>
<th>Contact angle (deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New-non coated clean insulator- non coated</td>
<td>45 - 55</td>
</tr>
<tr>
<td>2</td>
<td>New- coated clean insulator</td>
<td>100 - 110</td>
</tr>
<tr>
<td>3</td>
<td>New-non coated kaolin-salt polluted</td>
<td>10-20</td>
</tr>
<tr>
<td>4</td>
<td>New-coated kaolin-salt polluted</td>
<td>95 - 110</td>
</tr>
</tbody>
</table>
The table clearly indicates that RTV coating improves the hydrophobicity of new clean insulators significantly from contact angle of 45°-55° to 100°-110°. This changes the surface from hydrophilic to hydrophobic. Similarly, RTV silicone rubber coating maintains the hydrophobicity at kaolin-salt pollution with contact angle of 95°-110° which is almost the same value as at clean condition. However, contact angle for non coated insulator drops drastically to is 10°-20° which is a strong hydrophilic surface.

REFERENCES


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