Performance evaluation of modified multi gap arrester

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Abstract. The distribution network due to lightning strikes. There are several types of arresters to be developed. A modified multi gap arrester was tested to know its performance. The method used to determine its performance was done by comparing it with metal oxide type arresters through a series of laboratory tests. The testing consists of impulse test, salt fog test, and follow current interrupting test. The arrester performance related to residual voltage, breakdown voltage, and the ability to interrupt follow current were obtained through the tests. By knowing the performance of modified multi gap arrester, it can be used as a consideration in applying this technology related to the insulation stress of protected equipment and the potential for follow current phenomenon.

1. Introduction
Availability and reliability of services are the concerns of all the electricity company. Many transient conditions can disturb the reliability of electricity service, one of that is caused by the interference of lightning. Lightning can lead the line disturbance by direct strike or indirect strike. One of the efforts to prevent equipment failures due to lightning strikes is to install the line arrester in the network. Line arresters are installed to avoid flashover occurs on the insulator. At the moment of lightning strikes, arrester will conduct the lightning current in the line to the ground. It will cut the generated induction voltage in accordance with the characteristics of the current-voltage of the arrester. Another function of arrester is to prevent the occurrence of follow current. If the follow current happened, it will cause the protection relay to work and considered to be a phase-ground fault then the related line will be disconnected.

There are two general types of the arrester design, gap arresters and gapless arresters [1]. Utilization of gap arrester especially since it does not contact directly to the line. It makes arrester not to get stressed from the energizing line so arrester has less deterioration on its material. Another advantage of gap arrester is the isolating ability when fault occurs. It will cut the following current off so it does not make interference in the network. Based on its benefits, until now the design of gap-type arrester still continue to be developed.

Modified multi gap arresters that were tested consist of a series of gap electrode balls wrapped along with the insulating material. There are pressure relief holes parallel to the gaps. It serves as arc disposal when overvoltage applied to the arrester. The design scheme of the modified multi gap arrester is shown in Figure 1.
When the overvoltage applied to the modified multi gap arrester, discharge between gaps occur. The arc discharge makes the air temperature inside the gaps increase then the air pressure also become high. The pressure pushes the arc out the chamber into the air around the arrester.

2. Methodology
Along with the development of the new gap-type arrester design, it necessary provides some appropriate tests to verify the performance of the arresters. The testing scheme was conducted at the laboratory scale to get the performance characteristic of the modified multi gap arrester. The same test items were also carried out on the metal oxide arrester and the results were compared.

2.1. Voltage limited by arrester
The test on modified multi gap arrester and metal oxide arrester was conducted by giving impulse voltage on each tested arresters. The test installation can be seen in Figure 2. The amplitude of the impulse voltages test was complying with the value of basic insulation level (BIL) of the medium voltage equipment. The test voltage follows a standard lightning impulse voltage 1.2/50 with the voltage peak 125kV [2]. Five consecutive impulse at the test voltage were applied for each polarity to verify the voltage limited by arrester. Figure 3 show how each arrester suppress overvoltage to the equipment.
Figure 3. Voltage limited by modified multi gap arrester at 125kV impulse voltage (a), at -125kV impulse voltage (b); Voltage limited by metal oxide arrester at 125kV impulse voltage (c), at -125kV impulse voltage (d).

2.2. Effect of saltfog conditioning
Saltfog test was done by inserting a few samples of modified multi gap arresters into the chamber that contains the mist of salt. The test condition can be seen in Figure 4. Samples were left in a chamber for 30 days for a single period. Each completed period, impulse voltage was applied to each samples with different gaps (2 cm, 4 cm, 6 cm, and 8 cm) to the line and the result was observed. Those treatments were conducted for three times. The results of the treatments can be seen in Figure 5.

Figure 4. Saltfog conditioning chamber.
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Figure 5. Effect of saltfog conditioning to the limited voltage by modified multi gap arrester: at 125kV impulse voltage (a), at -125kV impulse voltage (b).

The test of breakdown voltage and leakage current were also conducted to the modified multi gap arresters after the last treatment period. The breakdown voltage test was done by increasing the power frequency voltage by 1 kV to measure the voltage when the current start flowing (breakdown occurs). After that increase the voltage to 15kV to ensure that the current was measurable and stable. The test results can be seen in the Table 1.

Table 1. Breakdown voltage and leakage current test result.

| Condition      | Sample | Voltage (kV) | Leakage Current (mA) | Information     |
|----------------|--------|--------------|----------------------|-----------------|
| Before saltfog | 1,2,3  | 13           | Fluctuate            | Start arcing    |
|                | 1      | 15           | 5                    |                 |
|                | 2      | 15           | 8                    |                 |
|                | 3      | 15           | 10                   |                 |
| After 3rd saltfog | 1,2,3 | 11           | Fluctuate            | Start arcing    |
|                | 1      | 15           | 2.8                  |                 |
|                | 2      | 15           | 2                    |                 |
|                | 3      | 15           | 3                    |                 |

2.3. Follow current test

The test was carried out to verify the performance of the modified multi gap arrester in breaking the follow current when lightning strike occurs and impacts to the energized line. Tests were carried out to the arresters with normal condition and with high pollutant inside the gaps. Block diagram of the test
and a laboratory test setup are shown in the Figure 6 [3]. The test circuit consists of three main components: AC voltage source (11.5 kV 50 Hz), impulse voltage source (125 kV 1.2 / 50 us), and the arrester under test. The test was done by giving impulse voltage on an energized conductor where the arrester was installed. Then the current and voltage waves were recorded as shown in Figure 7 and Figure 8.

![Block diagram and laboratory test setup](image1)

**Figure 6.** Block diagram (a) and laboratory test setup (b) for follow current interrupting test.

![Normal condition of voltage and current waveform](image2)

**Figure 7.** Normal condition of voltage waveform (a) and current waveform (b) for multi gap arrester during the follow current test.
Figure 8. Voltage waveform (a) and current waveform (b) during follow current phenomenon on high polluted multi gap arrester.

3. Result and discussion

Based on the waveform in Figure 3, the modified multi gap arrester has a steep voltage waveform when cutting the impulse voltage. The voltage of modified multi gap arrester was going to zero directly. While the metal oxide arrester has a residual voltage that is getting lower toward zero. Limited voltage of modified multi gap arrester is higher than metal oxide arrester. This high voltage will impose dielectric stress to the equipment. Frequent dielectric stress will degrade the insulation and if it occurs for a long time it will decrease the lifetime of the equipment.

Saltfog conditioning especially for samples of modified multi gap arrester is intended to accelerate the process of corrosion on the electrodes inside the arrester. Corrosion between electrodes will become impurities which may affect the arrester works. Figure 5 shows that saltfog conditioning make the limited voltage of modified multi gap arrester getting higher for each period. It indicates that the increasing impurities between gaps make the arc resistance increase too. The presence of impurities make the breakdown voltage of the gaps become lower. The leakage current is also smaller because the resistance is higher after experiencing 3rd treatment as shown in Table 1.

Follow current interrupting test was carried on modified multi gap arresters with normal condition and with polluted condition. When impulse voltage impact to the energized line, arrester with normal condition will discharge the impulse current and interrupt the follow current from the network. It appears that the voltage wave has some oscillation before back to its normal condition as shown in Figure 7. On the other hand, follow current phenomenon was happened on high polluted multi gap arresters because after arrester discharges the impulse current, it fails to cut the current off from the network. It makes the network current continues flowing until arrester disconnected from the network as shown in Figure 8.

4. Conclusion

The results of laboratory tests show that the voltage limited by a modified multi gap arrester is higher and much steeper than metal oxide arresters. The voltage generated by modified multi gap arrester
imposes dielectric stress to the equipment and decrease its lifetime. Saltfog conditioning triggers the production of impurities between the gaps. It will influence the performance of modified multi gap arrester to limit overvoltage, to interrupt follow current and it makes the arrester easily breakdown.

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