Development of Composite Line Spacers for Distribution Lines

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INTRODUCTION

Japan is surrounded by sea, and is frequently struck by typhoons and has a climate of high temperature and humidity especially in summer. Distribution facilities must be proof against this severe condition.

Polymeric insulators have the advantages of light-weight and toughness over porcelain ones. However, long-term reliability and performance against pollution are not yet clarified. In this paper, the results of screening tests of housing materials, structural examination and performance of newly developed polymeric inter-phase line spacers are presented.

EVALUATION OF LONG TERM RELIABILITY

Degradation of Polymeric Housing Materials

Polymeric materials are liable to be degraded or chemically decomposed by outdoor weathering such as ultraviolet rays ozone and acid rain. Surface discharges caused by natural contamination such as salt and dust generate erosion and tracking breakdown as shown in Figure 1.
Loss of hydrophobicity caused by surface degradation reduce anti-tracking performance.

Candidate Materials and Test Procedures

We selected several candidate materials as polymeric housing for long-term reliability tests. The base polymers are EPR (Ethylene Propylene Rubber), EVA (Ethylene Vinyl Acetate), and both LTV (Low Temperature Vulcanized) and HTV (High Temperature Vulcanized) – SR (Silicone Rubber).

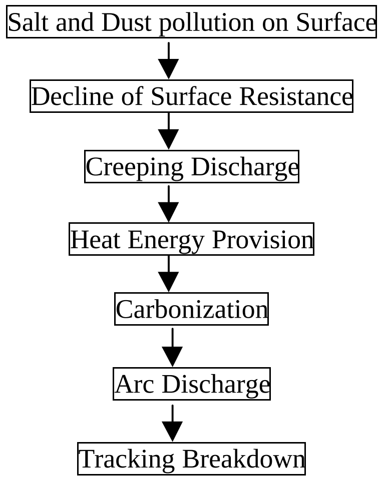


Figure 1. Mechanism of tracking breakdown process

All these materials are commercial compounds intended for outdoor high voltage use, appropriate fillers and additives have been blended beforehand.

The effects of weathering and ozone are evaluated by the tracking resistance of IEC Pub.60587.
We adopt sunshine carbon–arc method with water as a weathering test according to JIS D0205. This is a dominant evaluation method of ultraviolet rays effects on polymer materials in Japan. [1] We tested up to 5000h exceeding usual time of 2000h.
Ozone exposure is conducted in 100ppm for 70h. An English specification adopts the weather simulator of a combination of ultraviolet light exposure in 20pphm ozone concentration for 5000h.[2] The effect of 100ppm×70h exceeds that of 0.2ppm×5000h.
We measured contact angle as well as surface roughness before and after the artificial stress.[3]
Tracking resistance tests are conducted under constant voltage of 4.5KV until 6h. Figure 2 shows an example of tracking test arrangement.

Table 1. Time to tracking breakdown (hours)

Base Polymer	Filler[4]	Virgin	Weathering	Ozone	Weathering Ozone
EPR	Clay talc	0.29	0.03	0.38	0.11
EVA	$Al(OH)_3$	>6	>6	>6	>6
LTV-SR	$Al(OH)_3$, SiO_2	>6	3.33	>6	4.8
HTV-SR type A	$Al(OH)_3$	>6	>6	>6	>6
HTV-SR type B	$Al(OH)_3$, SiO_2	>6	>6	>6	>6

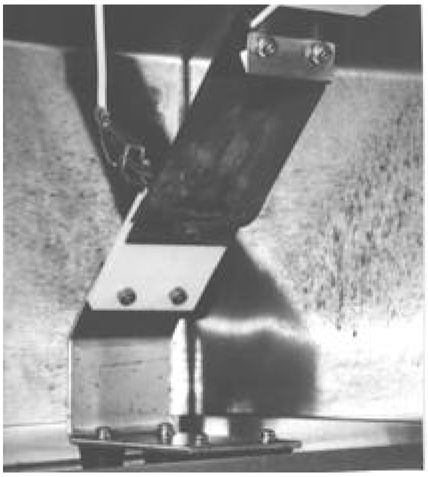


Figure 2. Inclined plate method tracking test arrangement (IEC 60587)

Figure 3. Field test site

Test Results

Contact Angle:
EPR showed decline of contact angle to 36°/65° from the initial value of 96°after weathering or ozone test respectively. Other materials maintained good hydrophobicity of over 80°after weathering.

Anti- Tracking Performance:
Table 1 shows summarized tracking test results. LTV-SR shows degradation after weathering test. EVA and HTV SR have good hydrophobicity and tracking resistance performance. EPR shows poor performance from the beginning.

Field Test

We have been testing above mentioned materials for five years in heavy pollution area. Figure 3 shows the test site, situated about 200m apart from the sea coast[5].

Figure 4 shows typical dimensions of the polymeric specimen. We measure the leakage current with applied voltages of 10kV (for acceleration), 4kV (normal line to earth voltage) and 0kV(without voltage application). Surface investigation has also been conducted.

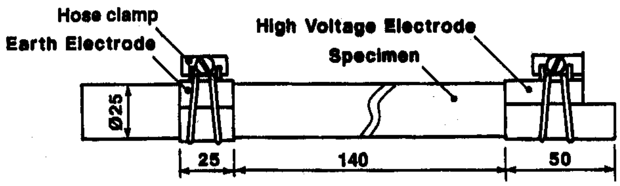


Figure 4. Typical dimensions of field test specimen

Table 2 shows the numbers of leakage current pulses measured on 10kV applied specimens during five years. EPR records by far large numbers of leakage current pulses. Figure 5 shows specimen of EPR; it began to reveal erosion and tracking after about four years, and to record surface discharges on rainy days. EPR has been successfully used for cable accessories in ordinary pollution area but it is not suitable for use in heavy salt contamination area.
LTV / HTV SR and EVA have been keeping excellent performances; changes of contact angle, surface roughness and chemical structures are negligible.

Table2. Numbers of leakage current pulses during five years (10KV)

Specimen	5 20mA	Above 20mA
EPR	62,915	690
EVA	269	62
LTV SR	6	0
HTV SR type A	0	0
HTV SR type B	0	0

Figure 5. Tracking of EPR specimen (4.5 years)

Both accelerated and long-term reliability tests show EVA and HTV- silicone rubber have good performance for the use of composite insulators applied in heavy salt pollution area.

DEVELOPMENT OF POLYMERIC LINE SPACERS

Needs for Distribution Line Spacers

Tokyo Electric Power Company (TEPCO) supplies electric power to the Kanto region, located in the center of Japan including great city of Tokyo. Historically in Japan, there are very few underground distribution facilities even in the populated area, and it is difficult to get adequate spaces to build distribution poles for various reasons. Application of line spacers can secure regulated intervals between high voltage lines and buildings without poles especially at corners. Figure 6 shows a typical example of its application on site.

Figure 6. Application of line spacers

Conventional porcelain made line spacers are applied in ordinary (not heavy pollution) area at present. They are open shed type and cannot be used in heavy pollution area. Protected shed (or bell) type has adequate pollution performance, but it is too heavy for supporting wires if made of porcelain. We expected to realize practical line spacers for heavy pollution area applying polymeric materials (EVA and HTV-SR) focusing on their advantages of light - weight and flexibility of shape.

Requirements

Table 3 shows summarized required performances of the polymeric line spacers. They should be lighter than the conventional porcelain ones used in ordinary pollution area. In Japan, overhead wires are covered (insulated) with PE or XLPE for public safety, there is a danger of leakage current on the surface of insulated wires. Leakage current should be restricted at low level to secure insulated wires. Above all, as overhead high voltage distribution systems are non-grounded in Japan, the leakage current must not exceed 200mA, which is the limit of earth fault protection relay.

Requirements of electrical performances are the same as those of line post insulators considering insulation coordination. As for mechanical performance, safety factor of 1.1 is secured against an extraordinary load which is total of wire weight, load caused by wind and electromagnetic repulsion force in case of short circuit.

Examination of Structure and Shape

Basic structure of the targeting polymeric line spacer is the same as conventional porcelain one; three independent insulators holding each line are assembled and united with a metal fitting which is connected to a earth wire. This structure is intended to restrain phase to phase flashover to occur in advance of phase to earth flashover. Figure 8 shows two shapes of trial insulator housings as well as conventional porcelain one.

Trial A (Protected shed or bell type)

This type of housing consists of one bell and two flat sheds. The combination of a bell and a upper flat shed is in common with the conventional porcelain line post insulators. Bell type can limit the leakage current by keeping inner surface dry. Flat shed is attached to protect invasion of rain and pollutants into the bell.

Figure 7 shows cross section of the trial product.

Trial B (Open shed type)

The shape is the same as the conventional one. Longer creepage distance and hydrophobicity of polymer are expected to diminish leakage current. This shape is easy to mold and cost is minimum.

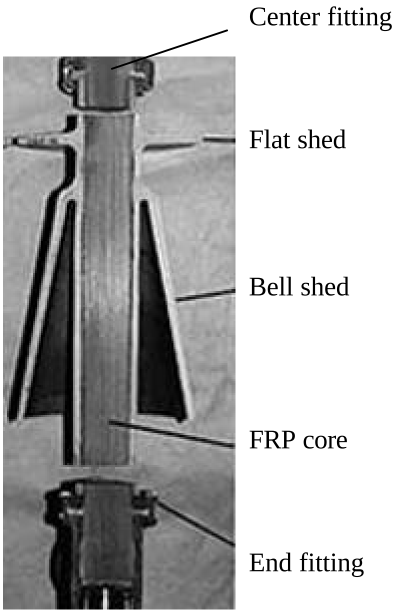
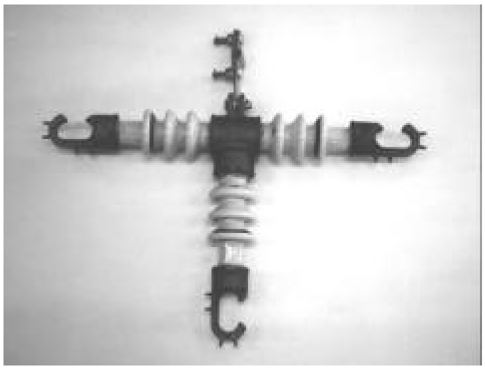


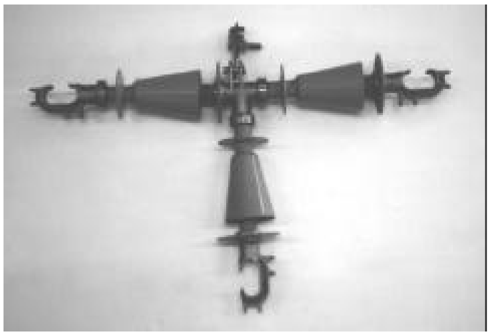
Figure 7. Partial cross section of trial A (Bell type)

Conventional porcelain made line insulator



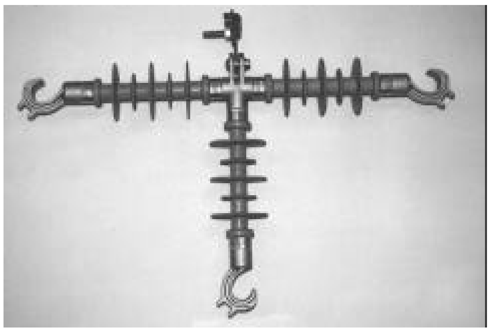
Total weight	4.6kg
Creepage distance	210mm
Cost comparison	100

Trial A (Protected shed or bell type)



Total weight	1.7kg
Creepage distance	450mm
Cost comparison	140

Trial B (Open shed type)



Total weight	1.5kg
Creepage distance	350mm
Cost comparison	80

Figure 8. Comparison of three types of line spacers

Examination of Performance

Table 3 shows summarized results of performance examinations
All the requirements are cleared in success. Pollution test was conducted by the solid layer method of IEC 60815 under equivalent salt deposit density of 0.35 mg /c (required value for heavy salt pollution area in Japan) . Both trial spacers A and B are qualified for heavy pollution use as far as pollution flashover voltages are concerned.

Table 3. Requirements and results of performance examinations

Test items		Trial A	Trial B
Power Frequency	Dry withstand (60kV 1min)		
	Dry FOV (70kV)	83.0kV	76.0kV
	Wet withstand (37kV 1min)		
	Wet FOV (50kV)	63.0kV	65.0kV
	5% FOV under pollution (7.2kV)	11.8kV	12.7kV
Impulse	Withstand Voltage (100kV)		
	Withstand 50%FOV (120kV)	139kV	140kV
Flexural breaking load (1.7kN)		4.4kN	2.4kN

Figure 9 . Flexural load breaking test (Trail A: Bell type)

Figure 9 shows the result of flexural load breaking test of Trail A (bell type); FRP was fractured at the metal fitting's end showing the bonding has enough strength

In addition to the test items shown in Table 3, we measured leakage current during contaminant liquid spray in order to evaluate the effect of the shape. Figure 10 shows test apparatus; a spacer specimen is set up as normal line to earth voltage of a.c. 4kV applied. Then contaminant liquid consisting of 40g Tonoko (powder of clay to eliminate the effect of hydrophobicity), 30g NaCl and 1kg tap water is sprayed at the rate of 1 / min from every direction. Continuous leakage current should be restricted under 1mA.

Table 4 shows the leakage currents of contaminant liquid spray test. Trial A (protected shed or bell type) is very effective in suppressing both basic and surge leakage currents. Trial B (open shed type) is also effective compared with the conventional porcelain one, the leakage currents record below one fourth of the latter.

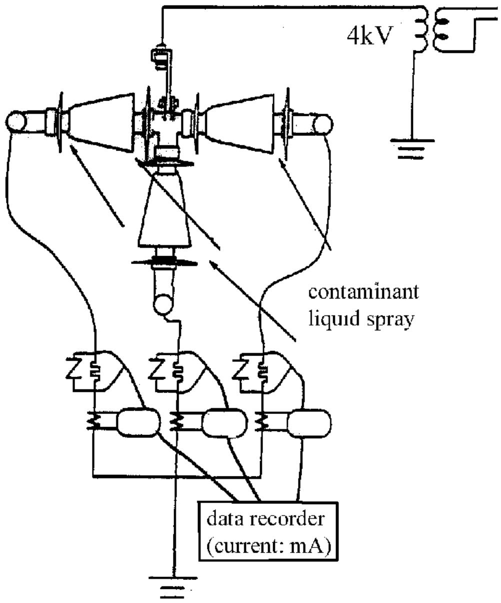


Figure 10. Leakage current test under contaminant liquid spray test

Table 4. Leakage Currents Under Contaminant Liquid Spray

Line Spacers	Surge current	Basic current
Conventional	200mA	26mA
Trial A (bell type)	< 1mA	< 1mA
Trial B	40mA	10mA

Conclusions

1. A series of long-term reliability tests (both accelerate and field test) have been done for polymeric housing materials, and finally EVA and HTV-SR are qualified for heavy pollution area's application.

2. Two types of polymeric line spacers are trial manufactured. One type (bell type) has good performance of suppressing leakage current, especially suitable for heavy salt pollution area, but a little costly. Another type (open shed) has an adequate performance to be used for ordinary pollution area, and cheaper than the conventional porcelain one.

3. Hereafter, we will apply those elemental technologies to the development of advantageous polymeric equipment for distribution system.

References

1 N.Yoshimura, S.Kumagai and B.Du, "Research in Japan on the Tracking Phenomenon on Electrical Insulating Materials", IEEE Electrical Insulation Magazine, Vol. 13, No. 5,PP. 8-19, 1997

2 Electricity Supply Industry Standard 09-13, Issue 1, October 1981, "Performance Specification for High Voltage Heat-Shrinkable Components for Use with High Voltage Solid Type Cables up to and Including 33000 Volts".

3 S.M.Gubenski, "Erosion resistance of Different Housing Materials to UV Irradiation and Surface Discharges Action" IEE Conf Publ,No.289,PP37-40,1988. Pub1,No.289, PP.37-40,1988

4 R.S.Goru "Performance of Polymer Insulating Materials in Salt-Fog Conditions", IEEE Trans. PWRD. Vol2 No.2,April 1987

5 R.G.Houlgate " Composite Rod Insulators for AC Power Lines :Electrical Performance of Various Designs at a Coastal Testing Station", IEEE Trans. PWRD. Vol5 No.4, November 1990