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DEVELOPMENT OF OUTDOOR-SEALING-END OF PREFABRICATED-COMPOSITE-INSULATOR FOR 66/77KV XLPE CABLE

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ABSTRACT

In power transmission field, the products which have merits of light weight, saving assembly time and low cost are demanded increasingly in these years. Especially in case of installation on transmission tower, considering accident of grounding fault, non-dispersion is required for bushing and inner insulation oil. We developed a new prefabricated composite insulator (named as PCI-66 hereinafter) type (fully solid composite) outdoor sealing end and have applied to the practice successfully for more than 2, 5 years. In this paper, we introduce the design concept and field experiences.

KEYWORDS

Prefabricated Composite Insulator, Solid insulator, Dry type outdoor sealing end

1. FEATURES OF THE OUTDOOR SEALING END OF PCI-66

Traditional type outdoor sealing end for 66/77kV XLPE cable is formed by heavy weight porcelain bushing and oil for internal insulation. All of its parts are assembled at the site. Thus, reducing the assemble time and labor-saving at the site was desired.

To meet the above requirements, we developed and applied a new type outdoor sealing end of prefabricated composite insulator for 66/77kV XLPE cable [1].PCI-66 has the following features.

1. Fully solid insulated construction. Formed by directly molded silicone rubber on the surface of epoxy resign. (Fig.1)
2. Completely dry type sealing end using neither oil nor gas for internal insulation. It can be installed also either horizontally or upside-down without using special fitting.(Fig.2)
3. High reliability. Body is pre-assembled and inspected at the factory before shipment. (Fig.3)
4. Fewer parts, less assembling time at site are possible by applying Plug-in construction. (Fig.4)
5. The weight is very light. Compared with the porcelain type sealing end, it is easer to handle. (Table 1)
6. High dielectric characteristic for pollution. It is usable in very heavy pollution environment with the same length as the porcelain type sealing end for light pollution environment. (Fig. 5)

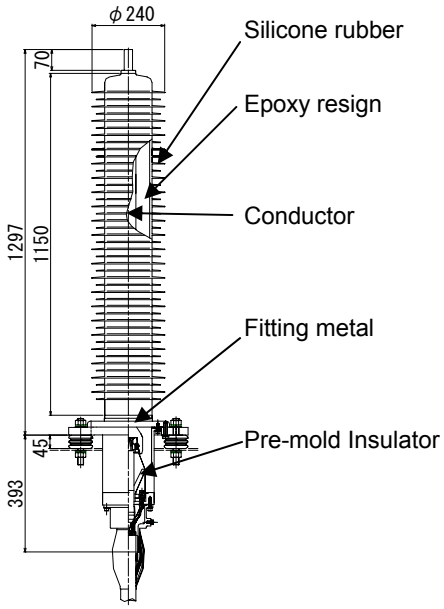

Figure 1: Structure of PCI-66

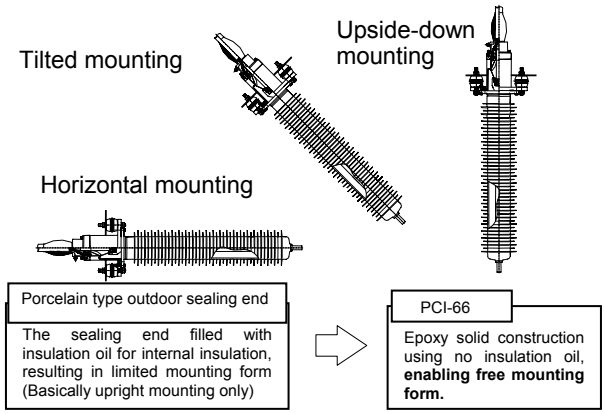

Figure 2: Free mounting form

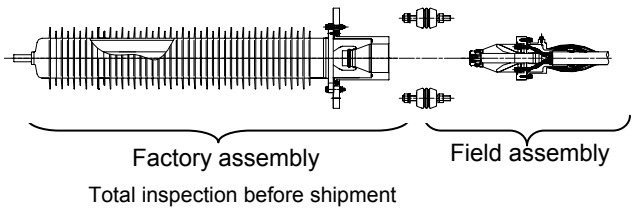

Figure 3: Plug-in construction of PCI-66

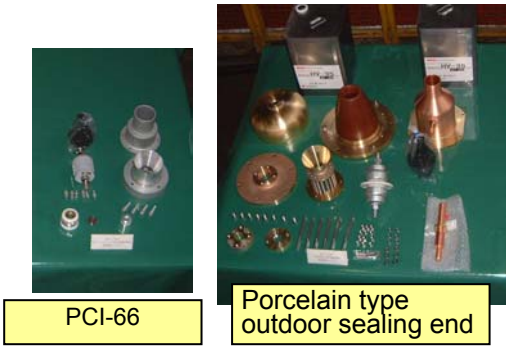

Figure 4: Comparison of assembly parts at the site

Table 1: Comparison of outdoor sealing ends

Item	PCI-66	Porcelain bushing	
		light pollution	very heavy pollution
Weight	Approx. 80kg	Approx. 180kg	Approx. 235kg
Average radius	195mm	265mm	265mm
Overall length	1297mm	1322mm	1897mm
Leakage distance	3973mm	2600mm	4080mm

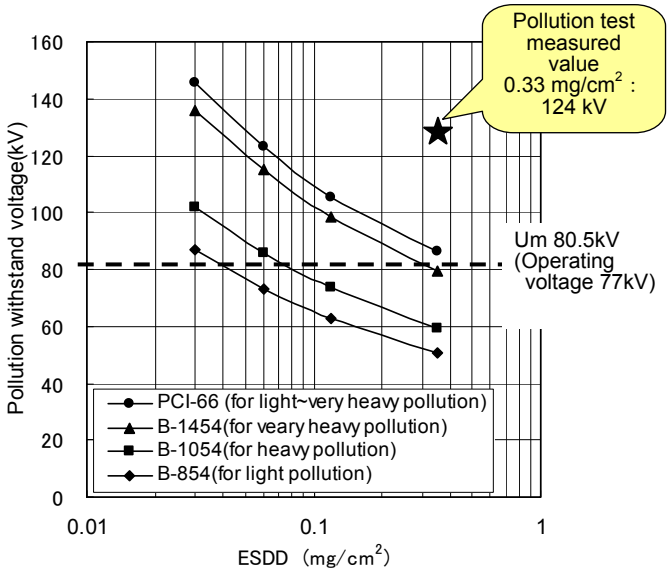

Figure 5: Comparison of pollution withstand voltage to Equivalent salt deposit density (ESDD) [2]

2. DEVELOPMENT TESTS

2-1 Electrical test

We have conducted the development tests in accordance with JEC-3408 and verified that PCI-66 has outstanding performance as a 66/77kV sealing end as shown in Table2, Table3 and Figure6.

Table2: results of electrical test

Item	Conditions	Result
Power frequency withstand voltage test	150kV 1hours	Good
Impulse withstand voltage test	+-550kV/ 3times	Good
Partial discharge test	95kV <5pC	Good
Long period heating cycle voltage test	65kV 8h on/16h off 90degree 153times 105degree 30times	Good

Table3: Results of flashover voltage test

Items	Results
Wet power frequency flashover voltage test	232kV
Wet impulse flashover Voltage test（Polarity "-"）	612kV
Wet impulse flashover voltage test（Polarity "+"）	697kV
Dry power frequency flashover voltage test	237kV

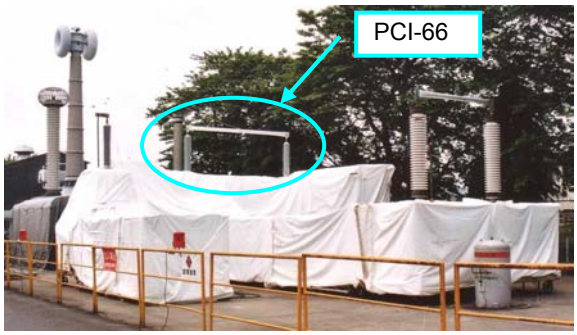

Figure 6: Long period heating-cycle voltage test

2-2 Artificial pollution test

As shown in Figure5, we calculated the pollution withstand voltage characteristic of PCI-66 basing on the pollution characteristic of porcelain type sealing end [2]. Normally, it is considered that the smaller radius of sealing end with same creepage distance has better performance. Therefore, the pollution withstand voltage characteristic of PCI-66 is better than that of porcelain type sealing end in the theory because of its smaller radius.

To verify the dielectric characteristic for pollution, artificial pollution test by equivalent fog flashover method was conducted. In very heavy pollution condition [the equivalent salt deposit density (ESDD): 0.33 mg/cm^2] the equivalent fog 5% flashover voltage was 124 kV as shown in Figure5. This test result is far higher than Um 80.5kV of the 77kV class. We think this difference is result of the great hydrophobic characteristic of silicone rubber. The test proves that PCI-66 has excellent dielectric characteristic for pollution as shown in Table4 and Figure7.

Table4: Results of artificial pollution test

Items	Results
Equivalent salt deposit density (ESDD)	0.33mg/cm2
Flashover voltage	135～187kV
5% flashover voltage	124kV

Figure 7: Artificial pollution test

2-3 Ground fault test

The safety in accident was confirmed by ground fault test of 2kA/2seconds. In the test, PCI-66 did not burst and disperse at all as shown in Table5 and Figure8-10.

Table5: Results of ground fault test

Case	Parts of ground fault conductor	Results
1	between epoxy bushing and pre-mold insulator,	Good
2	for pre-mold insulator	Good
3	for epoxy bushing	Good

Figure 8: After Ground fault test (case1)

Figure 9: After Ground fault test (case 2)

Figure 10: After Ground fault test (case3)

2-4 Cantilever load test

Cantilever load test considering total load of wind pressure, earthquake, and short-circuit electromotive force was conducted. After applied cantilever load of 2940N (300kgf), PCI-66 showed good result in withstand voltage test. Two times or more the possible total load, to PCI-66 and found that no partial discharge occurred as shown in Table6 and Figure11.

Table6: Condition of cantilever load test

Items			Notes
Moment (N･m)	Load for wind	388	Wind speed 40m Atmospheric pressure 760mmHg Temperature 15℃
	Load for earthquake	249	Acceleration 0.3G Lead line 1000mm2 HDCC 5m
	Load for Electric magnetic force	639	Short circuit current I=31.5kA Distance of sealing end 1.1m Lead line 5m
	Total	1276	-
	Total×2	2550	-
Sample length(m)		1.1	-
Assumption load(N)		2300	Assumption load =total moment× 2/sample length
Load of bending test(N)		2940	-

Figure 11: Cantilever load test

3. MOUNTING INSULATOR

We developed mounting insulator by hydrophobic epoxy resign. The hydrophobic epoxy resign is much better than ordinary epoxy resign for hydrophobic characteristic [3]. We conducted electric tests and mechanical tests. The test results of the mounting insulator have been good as shown in Table7 and Figure12.

Table7: Results of development test for mounting insulator

Items	Characteristic	Result
Cantilever load test	9.8kN	Good
Tensile test	21.6kN	Good
Torque test	206N·m	Good
Impulse withstand Voltage test	-40kV/3times	Good
Impulse flashover Voltage test	JIS C 3801 7.8	-69kV

Figure12: Cantilever load test for mounting insulator

4. ENVILOMENTAL TEST

4-1. Weathering test

We conducted weathering test for silicone rubber and hydrophobic epoxy resign. The surface condition after irradiating of UV 6000h has been monitored. Water contact angle(θ_w) and surface resistance(ρ_s) did not change after the test as shown in Figure13-14.

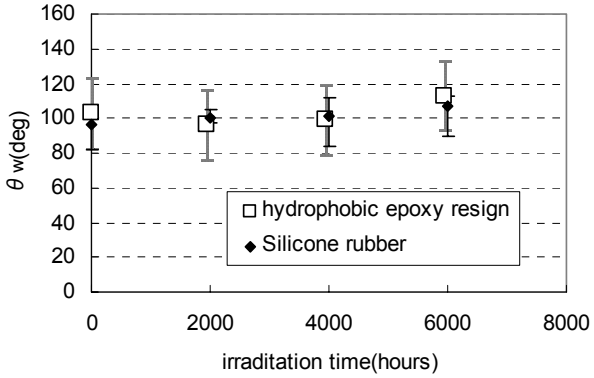

Figure13: θ_w vs. Irradiation time characteristic

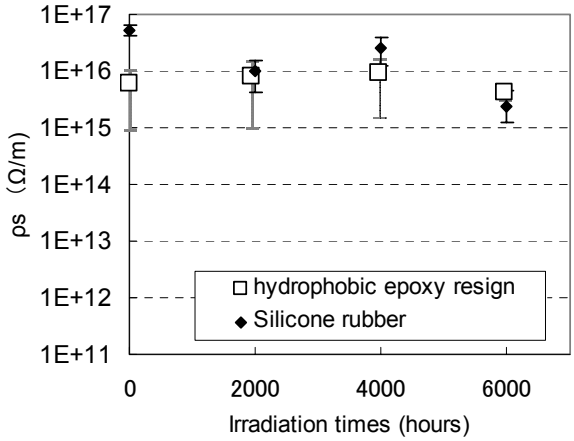

Figure 14: ρ_s vs. Irradiation time characteristic

4-2. Heat-cycle test

We conducted heat-cycle test with test condition of rising from -40degree 3hours to 90degree 3hours by 12cycles. The performance has been checked by partial discharge test. The result was good.

5. ASSEMBLY SITUATION AT THE SITE

PCI-66 has been applied in practice over 150 phases.

We install the sealing ends on transmission towers and on grounds. The weight of PCI-66 is enough light to handle that one or two person can competent by hand. And we can assemble within 2days compared 3days for porcelain type. Figure15 shows assembly situation in the field.

The reason of less assembling time is described below.

1. PCI-66 applies Plug-in construction.
2. Main body of PCI-66 is almost pre-assembled at the factory before shipment.
3. The assembling parts are few at site.
4. The weight of PCI-66 is so light that it is easer to handle.

By practical application, it is shown that PCI-66 can be assembled more speedy and safety than porcelain type.

This is an excellent merit for transmission tower as its difficult assembling.

Figure 15: Assembly situation in the field

6. FIELD EXPERINECE

We checked the field aged PCI-66 after 1.5years by hydrophobic characteristic, partial discharge, withstand voltage test. There is no reduction of hydrophobic characteristic or damage was observed as shown in Table8.

Table 8: hydrophobic characteristic

Terms in service	Initial	18 months
Hydrophobic situation		
STRI	HC1	HC1

7. CONCLUSION

We developed an outdoor sealing end of prefabricated-composite-insulator (PCI-66) formed by directly molded silicone rubber on the surface of epoxy bushing. PCI-66 is a dry type, light weight, and plug-in type sealing end. And PCI-66 has high dielectric characteristic for pollution. Therefore, it is possible to simplify setting stand and reduce assembling time. And it is not necessary to select the pollution level of bushing. As a result, the total cost can be reduced greatly.

PCI-66 has sufficient performance as a 66/77kV class sealing end.

The field aged PCI-66 after 1.5years was checked. And no damage or degradation was observed on PCI-66.

At last, we would like to thank Tyco Electronics AXICOM for special help of this development.

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