Polymer-housed Surge Arresters Compliant with JEC-2374:2020 Standard

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Abstract

Polymer-housed surge arresters are smaller and lighter than porcelain-housed surge arresters, and offer superior seismic resistance and ease of handling. Furthermore, they possess many advantages, such as improved resistance to fouling, leading to increased adoption of polymer-housed surge arresters. In 2020, the surge arrester standard in Japan JEC-2374 was revised, and polymer-housed surge arresters were standardized [1].

In 2014, our company developed the ZS-G series of polymer-housed surge arresters for station class. At that time, the JEC standard for polymer-housed surge arresters had not yet been established, so the design was based on IEC standards, the then-established JEC surge arrester standard, and technical reports. Subsequently, in 2020, with the establishment of the JEC standard for polymer-housed surge arresters, we conducted re-tests using the specified type test items for polymer-housed surge arresters. As a result, we confirmed that the ZS-G series satisfies the JEC Standard specifications required for polymer-housed surge arresters.

1 Preface

Compared to porcelain-housed surge arresters, polymer-housed surge arresters are smaller and lighter, making them easier to transport and install, and further improving the safety factor for seismic resistance. In addition, the water-repellent surface of the outer casing improves resistance to fouling. For these reasons, the adoption of polymer-type surge arresters has been increasing in recent years.

The test methods for polymer-type surge arresters were discussed in the JEC (Japanese Electrotechnical Committee) Technical Report published in 2008, and the design methods and test contents were proposed in the Electrical Cooperation Research Vol.72 No.4 “Standardization of Design Standards and Test Methods for Polymer Insulators”[2], published in 2017. Subsequently, the 2020 revision of JEC-2374 provided the first formal standardization of polymer-housed surge arresters and specified design parameters such as the required creepage distance and shed profile.

Furthermore, in the type testing, bending moment tests and weather resistance tests were added as tests specific to polymer-type surge arresters, and some of the test methods for the pressure release test and fouling test were also modified.

In 2014, our company developed the ZS-G series of surge arresters for power generation and substations (for nominal voltages of 22 to 275 kV), referring to JEC and IEC standards and technical reports that were in publication at the time. Subsequently, polymer-type surge arresters were added to the standards, so we confirmed compliance and verified the type testing in accordance with this JEC standard, and confirmed that all items yielded good results. This paper introduces some of the JEC-2374:2020 type testing conducted on our company’s polymer-housed surge arrester, the ZS-G series.

2 Product Specifications

Table 1 shows the main specifications of the ZS-G series. The ZS-G series is a surge arrester for station class applications, applicable to system voltages of 22 to 275 kV (switching surge discharge withstand capacity class D to B). The shed profile

Table 1 Main Specifications of the ZS-G Series

The main specifications of the ZS-G series are shown. It is a product compatible with nominal voltage of 22 to 275 kV, and is compatible with allowable salt adhesion densities up to 0.35 mg/cm² (class B is 0.25 mg/cm²).

Item		Rated								
Type		ZS-G1PH (X)		ZS-G1PK (X)						
Rated voltage (kV)		28	42	70※1	84	98	112	126	140	196
System voltage (kV)		22	33	※2	66	77	※2	※2	110	154
Types of lightning arresters		Standard type arrester		Surge arrester with low protection level						
Nominal discharge current (kA)		10								
Reference voltage (kV)		39.6	59.4	99	119	139	158	178	198	277
Switching surges discharge durability class		D		C						
Residual voltage	Steep current impulse (at 10 kA) (kV)	103	154	210	248	294	334	377	419	586
	Lightning impulse (at 10 kA) (kV)	94	140	191	229	267	304	343	381	533
	Switching impulse (at 1 kA) (kV)	90	120	170	204	239	272	307	341	477
Shortcircuit current (kA)		63								
Pollution resistance category (allowable salt adhesion density) (mg/cm²)		Standard form: 0.01 Pollution resistant type: 0.03～0.35								

Item		Rated									
Type		ZS-G2PK (X)									
Rated voltage (kV)		84	98	112	126	140	196	182	210	266	280
System voltage (kV)		66	77	※2	※2	110	154	187	220	275	275
Types of lightning arresters		Surge arrester with low protection level									
Nominal discharge current (kA)		10									
Reference voltage (kV)		119	139	158	178	198	277	232	267	339	356
Switching surges discharge durability class		BB						B			
Residual voltage	Steep current impulse (at 10 kA) (kV)	248	294	334	377	419	586	452	521	660	695
	Lightning impulse (at 10 kA) (kV)	229	267	304	343	381	533	411	474	600	632
	Switching impulse (at 1 kA) (kV)	204	239	272	307	341	477	370	430	540	570
Shortcircuit current (kA)		63									
Pollution resistance category (allowable salt adhesion density) (mg/cm²)		Standard form: 0.01 Pollution resistant type: 0.03～0.35						Standard form: 0.01 Pollution resistant type: 0.03～0.25			

Notes: ※1. Since the voltage limit is 15% lower than the JEC-217 standards, it was a high performance lightning arrester.
※2. For neutral points

Fig. 1 The Appearance of the ZS-G Series

and required surface creepage distance are designed to satisfy JEC-2374:2020, and the allowable salt deposition density is up to 0.35 mg/cm² (0.25 mg/cm² for class B). Fig. 1 shows the exterior of the ZS-G series.

3 Type Tests

New tests have been added to the type testing of polymer-housed surge arresters in JEC-2374:2020. Also, some tests previously performed on porcelain-housed surge arresters have been modified. This section describes the results of the pollution test, bending-moment test, weathering test, and the evaluation of polymer-housing properties, all of which were re-verified in this study.

3.1 Pollution Test

In the contamination test of JEC-2374:2020, provisions have been added not only for the equivalent salt deposit density (ESDD) during fouling, but also for the amount of non-soluble substance deposited (NSDD).

Furthermore, polymer-housed surge arresters are required to have their water repellency removed before testing, and a new procedure has been established for this. This is to simulate the loss of water repellency on the surge arrester surface due to rapid fouling and moss, and to verify the fouling resistance performance under severe conditions.

In the test, the water repellency was first removed using the slurry method. The slurry method involves applying a mixture of water and powder to the entire surface of the test specimen, and then gently washing it after drying to remove the water repellency. Fig. 2 shows the surface of the test specimen after the fouling solution was sprayed on it after the water repellency had been removed. The fouling solution spreads smoothly across the surface of the cap, confirming that the water repellency has been removed. Subsequent fouling was performed using the equivalent mist method, and the equivalent salt deposition density of the fouling solution was adjusted to be equal to or greater than the specifications of the test specimen. Furthermore, the amount of powder was adjusted so that the insoluble substance deposition density was 0.3 mg/cm^2 or higher.

In the fouling withstand voltage evaluation, a short-time overvoltage superposition test was performed on the fouled test specimen. Fig. 3 shows the test specimen during voltage application. No flashover occurred in any of the test specimens during voltage application, confirming that the fouling resistance performance was satisfied.

3.2 Bending Moment Test

The bending moment test evaluates whether the polymer-housed surge arrester can withstand the load it receives during use. This is a test specific to polymer-housed surge arresters. Fig. 4 shows the sequence of the bending moment test for polymer-housed surge arresters used in 66 kV systems and above. This test consists of a load test to verify the load-bearing capacity against bending and a water immersion test to confirm the adhesion between the polymer sheath and internal components. Electrical characteristics are measured before and after the test, and pass/fail is determined based on the presence or absence of changes.

The load test is conducted in two types: specified long-term load (SLL) and specified short-term

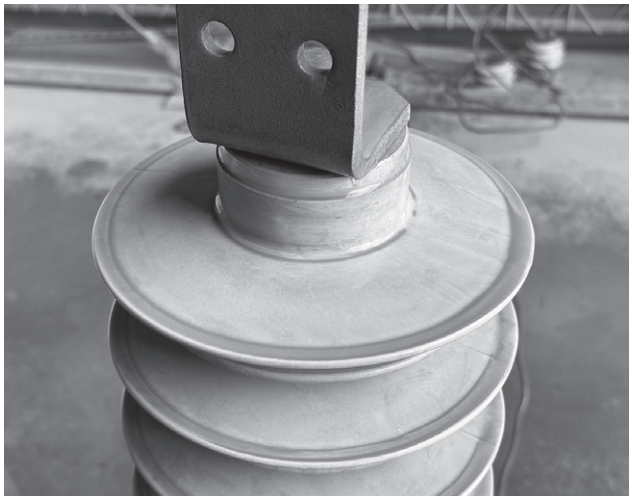


Fig. 2 The Surface of the Test Instrument Sprayed with Fouling Liquid

Contamination liquid is sprayed so as to cover the surface of the test device, and it can be confirmed that hydrophobicity has been removed. In the fouling test, it is evaluation that predetermined pollution resistance is ensured even if water repellency disappears in this way.

Fig. 3 Test Device while Voltage is Being Applied

A short-term overvoltage superposition test was performed at all ratings, and no flashover occurred. It was confirmed that the specified pollution resistance performance was satisfied.

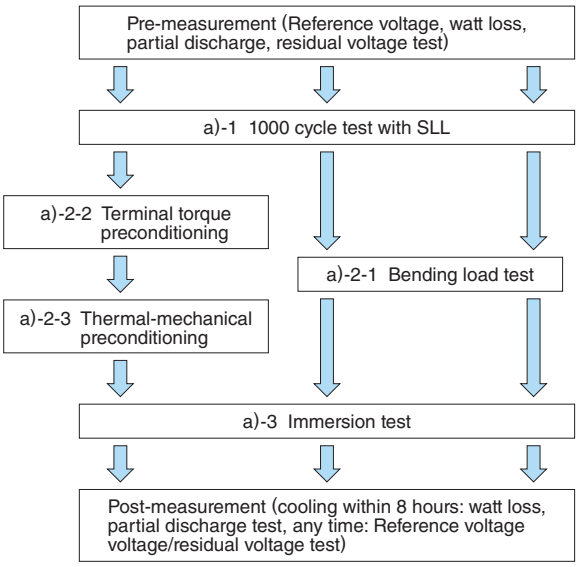


Fig. 4 Bending Moment Test Sequence

The bending moment test is performed with three test devices. This test is a complex test in which electrical tests, bending tests, immersion tests, etc. are performed.

load (SSL). Long-term load-bearing considers continuous and repeated loads such as wind pressure loads and loads from connected wires. This load is verified by a 1000-cycle alternating load test and thermal and mechanical preconditioning tests. On the other hand, short-term load-bearing considers temporary loads such as loads generated during earthquakes and loads due to electromagnetic forces during short circuits, and is evaluated by a bending load test.

After these load tests, the test equipment is boiled in salt water for 42 hours as a water immersion test to evaluate the penetration of moisture into the interior. In this test, to confirm that the adhesion between the polymer outer shell and the internal unit has not delaminated due to the load test, waveform confirmation during residual voltage measurement and partial discharge tests are performed after boiling. This confirms and evaluates that there is no intrusion of moisture into the interior.

Fig. 5 shows the thermal-mechanical preconditioning process. In this test, the load is applied for a long period of time while changing the temperature and load direction every 24 hours. Fig. 6 shows the immersion test. In this test, the test specimen is boiled in salt water at approximately 100℃. After these tests, electrical tests were performed, and the rate of change compared to the results of the electrical tests performed before the tests was all within the standard values. Furthermore, the limiting voltage

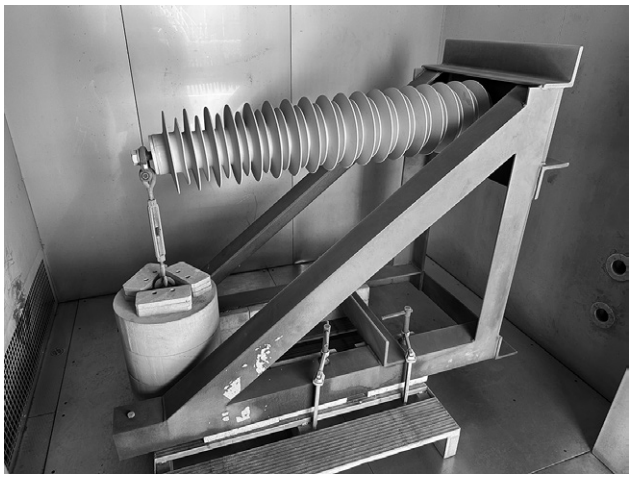


Fig. 5 Thermal-Mechanical Preconditioning

The test is performed by changing the temperature and load direction every 24 hours. Mechanical stress is applied while changing the temperature from high temperature to low temperature from +60℃ → −25℃ → +45℃ → −40℃.

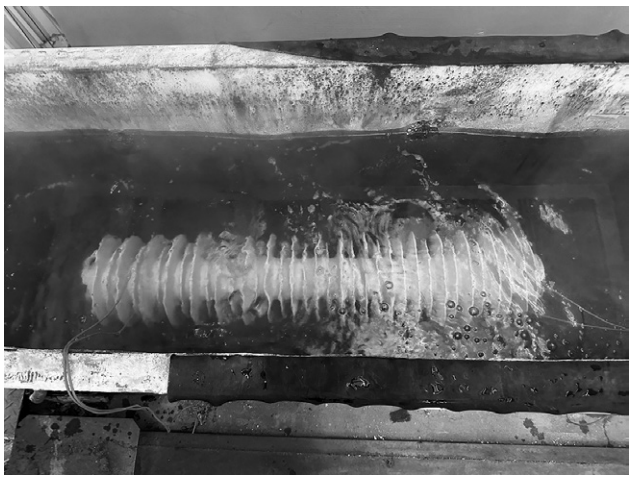


Fig. 6 Immersion Test

Boil for 42 hours in 1 kg/m³ NaCl aqueous solution. The moisture intrusion resistance characteristics of the polymer lightning arrester's housing and internal parts are pre-verification.

waveform remained unchanged from before the tests, and there was no evidence of water intrusion. Based on these results, the ZS-G series showed good results in the newly defined bending moment test.

3.3 Weather Ageing Test

The weathering test evaluates the durability of the polymer coating. JEC-2374:2020 specifies a salt fog test and an UV light test.

The 1000-hour salt mist test evaluates degradation phenomena such as tracking and erosion that occur on the surface of the polymer coating. The test apparatus is placed indoors filled with salt

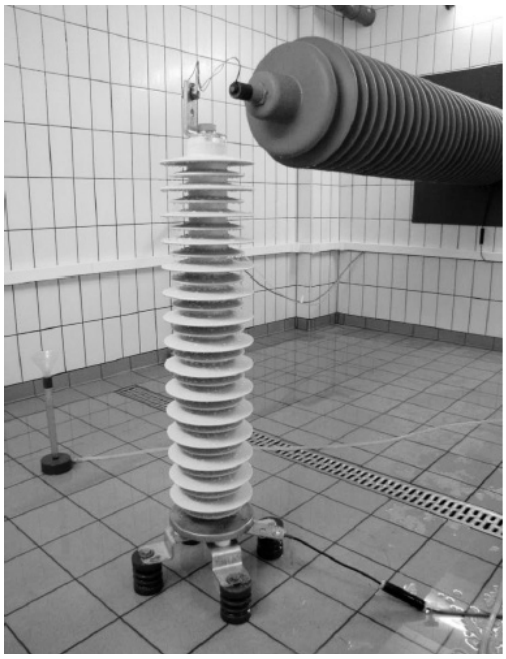
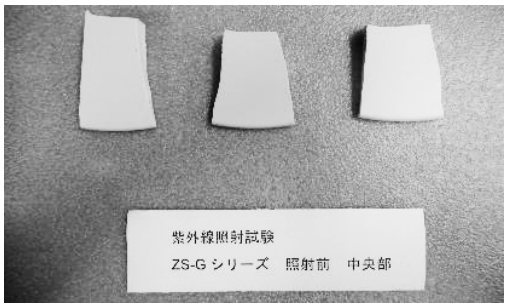


Fig. 7 Salt Fog Test

Voltage is applied for 1000 hours in salt fog. There were no changes in appearance or electrical properties after testing.



(a) Before the test

(b) After the test

Fig. 8 Samples before and after UV Light Test

There were no changes in appearance or surface roughness before and after the test.

mist and energized for 1000 hours. Fig. 7 shows the salt mist test. After the test, the test apparatus showed no visible abnormalities on the coating surface, such as tracking or erosion that revealed the substrate, and there was no change in electrical properties before and after the test.

The ultraviolet irradiation test evaluates whether cracks or erosion occur due to degradation of the coating by ultraviolet light. A sample of polymer material is irradiated with ultraviolet light for 1000 hours using the xenon arc method, and the material is evaluated by measuring changes in appearance such as cracks and surface roughness. Fig. 8 shows samples before and after the UV light test. No visible changes were observed before and after irradiation, and there was virtually no change in surface roughness, confirming that there was almost no effect of degradation due to UV light.

These tests confirmed that the weather resistance of the ZS-G series is good.

3.4 Tests on the Housing Material of Polymer-Type Surge Arresters

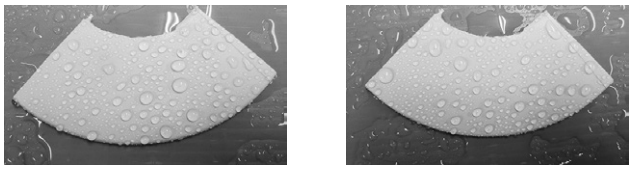
JEC-2374:2020 specifies the characterization of housing materials used in polymer-type surge arresters as Annex D (Normative Tests) and Annex E (Reference Tests). These tests aim to measure the reliability and characteristics of polymer materials. They also recommend obtaining data for considering future degradation evaluation methods for polymer enclosure materials. Table 2 shows a list of test items. While pass/fail criteria are defined for the normative tests, the reference tests do not have judgment criteria; only measured values are obtained.

Table 2 List of Test Items for Housing Materials for Polymer-Housed Arresters

The prescribed exam is an item for which acceptance criteria have been determined, and reference tests have not been determined. These tests are recommended to examine the evaluation of polymer outer skin materials in the future.

Test classification	Test items
Normative test (Annex D)	Hardness testing of polymer materials Flammability tests for polymer materials
Reference (Annex E)	Inclined plate method tracking resistance and erosion resistance test Arc resistance test Contact angle measurement test Water repellent recovery characteristic test Peel test

Our company conducted all required tests on the silicone rubber used for the housing of our polymer-housed surge arresters. In the hardness test specified by regulations, there was no change in hardness before and after boiling. Furthermore, in



(a) Before wiping　　(b) 30 minutes have passed since wiping

Fig. 9 Results of Hydrophobicity Recovery Properties Tests

It can be seen that there was no change in hydrophobicity before the hydrophobicity was lowered and 30 minutes after it was dropped, and it has recovered.

Fig. 10 Water Repellency of Outdoor Exposure Testers

The water sprinkled on the surface of the test specimen, which had been exposed outdoors for 20 years, has become polka dots due to water repellency.

the combustion test, it achieved the highest flame retardancy rank of V-0, passing all tests. In the reference test for water repellency recovery characteristics, after reducing the water repellency of the sample, the recovery time was confirmed to be within 30 minutes. Fig. 9 shows the results of the hydrophobicity recovery test. It was also confirmed that this hydrophobicity has been maintained in the test specimens used in the outdoor exposure test that has been conducted at our Numazu Works for 20 years. Fig. 10 shows the condition of the outdoor exposure test specimen when its hydrophobicity was checked. These results confirmed that hydrophobicity is maintained even when the surface is contaminated.

Through these material evaluations, it was confirmed that the silicone rubber used in our polymer-housed surge arresters possesses excellent properties as power equipment. These results will be utilized in future studies on the evaluation of degradation in polymer housing materials

4 Postscript

Polymer-housed surge arresters have many advantages compared to porcelain-housed surge arresters, including smaller size, lighter weight, and superior fouling resistance. Furthermore, with the establishment of the JEC Standard, their adoption is expected to increase further. By updating the ZS-G series to comply with the latest JEC Standard, we believe we can contribute to the widespread adoption of polymer-housed surge arresters.

Going forward, we intend to continue providing our customers with high-quality polymer-housed surge arresters that meet societal needs, utilizing the surge arrester technology and polymer molding technology we have cultivated.

・All product and company names mentioned in this paper are the trademarks and/or service marks of their respective owners.

《References》

(1) "JEC-2374:2020 Metal-Oxide Surge Arrester," The Institute of Electrical Engineers of Japan Electrical Standards Committee, 2021

(2) "Standardization of Design Criteria and Test Methods for Polymer Insulators," The Japan Electrical Engineering Cooperative Association, Vol.72, No.4