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IEEE Guide for Application of Composite Insulators

IEEE Power Engineering Society

Sponsored by the
Transmission and Distribution Committee

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(Revision of IEEE Std 987-1985™)

IEEE Guide for Application of Composite Insulators

Sponsor

Transmission and Distribution Committee
of the
IEEE Power Engineering Society

Approved 30 April 2002

American National Standards Institute

Approved 6 December 2001

IEEE-SA Standards Board

Abstract: A guide to the application of composite insulators to overhead transmission and distribution lines is provided. It is based on utility field experience, results of research laboratory tests, and manufacturers' recommendations. The guide deals with composite insulators, which include a core, weathersheds, and metal end fittings. The core consists of resin and axially-aligned glass fibres. The weathersheds are of polymeric materials.
Keywords: composite insulators, non-ceramic insulators, polymer insulators

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Introduction

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Since the first application guide, great strides have been made in the understanding of polymer material properties and composite insulator design characteristics. Of the few remaining concerns that utilities have today in using composite insulators, surely the greatest ones are on the aging and life expectancy of these insulators. Initially weathering was considered to be the main factor in limiting life. Although weathering has been shown to age polymer materials, there is a growing body of experience suggesting that composite insulator life is more related to design characteristics and/or quality control during their manufacture. With present day polymer material technology used in good designs and with good quality control during their manufacture, it is entirely feasible to produce composite insulators that will have adequate service life. There are installations where polymer insulators have been in service for more than 25 years.

This application guide is founded on field experiences, laboratory tests, and on manufacturers' recommendations. It was prepared by a task force of the working group on Non-Ceramic Insulators, Lightning and Insulator Subcommittee, Transmission and Distribution Committee of the IEEE Power Engineering Society. At the time this guide was approved, G. G. Karady was the chairman of the working group. J. Kuffel served as the chairman of the task force and was instrumental in guiding development of this guide. The task force members were as follows:

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IEEE Guide for Application of Composite Insulators

1. Overview

1.1 Scope

This is a guide for the application of composite insulators to overhead transmission and distribution lines. It is based on utility field experiences, results of research laboratory tests, and manufacturers' recommendations.

The guide deals with composite insulators, that include a core, weathersheds, and metal end fittings. The core consists of resin and axially-aligned glassfibres. The weathersheds are of polymeric materials.

2. References

This guide shall be used in conjunciton with the following publications. When the following specifications are superseded by an approved revision, the revision shall apply.

ANSI C29.11-1989, Composite Suspension Insulators for Overhead Transmission Lines—Tests.[1]

IEC 60383-1 (1993-04), Insulators for overhead lines with a nominal voltage above 1000 V— Part 1: Ceramic or glass insulator units for a.c. systems— Definitions, test methods and acceptance criteria.[2]

IEC 61109 (1992-03), Composite Insulators for a.c. overhead lines with a nominal voltage greater than 1000 V— Definitions, test methods and acceptance criteria.

IEEE Std 1024-1988™, IEEE Recommended Practice for Specifying Distribution Composite Insulators.[3]

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[1]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[2]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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3. Definitions

These definitions apply specifically to composite insulators. IEEE 100™, *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition [B14][4], should be referenced for terms not defined in this clause.

3.1 Structural terms

The following terms apply to the physical composition of the insulator:

3.1.1 core: The axially aligned fibre reinforced resin rod that forms the mechanical load-bearing component of the insulator.

3.1.2 end fittings: The insulator attachment hardware that is connected to the core.

3.1.3 grading device: A device for controlling the potential gradient at the end fittings, such as a metal ring or various semiconductive polymeric devices.

3.1.4 housing: The external polymeric covering installed over the core to afford it protection. Depending upon the design of the insulator the housing may comprise a separate or integral sheath-weathershed system. In both cases, the weathersheds provide the wet electrical strength and leakage distance, while the sheath provides the core with protection between weathersheds and near the end fittings.

3.1.5 phase-to-phase insulator: An insulator coupling two phases together as a means for controlling conductor spacing during galloping. It is intended to be loaded in tension, torsion, bending, or compression.

3.1.6 post insulator: Any insulator intended to be loaded in tension, bending, or compression. The most common types are a horizontal line post where the post projects nearly horizontally from a pole and is loaded in flexure by the conductor, and a station post insulator used as a bus support in an outdoor substation. When post insulators are used in disconnect switch applications, they may also be loaded in torsion.

3.1.7 suspension insulator: Any insulator intended primarily to carry tension loads. It includes tangent, dead-end, and V-string installations.

3.2 Electrical terms

The following terms apply to electrical phenomena that may occur on shed material during service. For additional information see the bibliography given in Annex A.

3.2.1 erosion: The loss of material by the physical action of leakage current, corona discharge, or dry band arcing.

3.2.2 maximum design withstand load (MDWL): The maximum cantilever load in service that the insulator is designed to carry.

3.3 Mechanical terms

The following terms apply to the mechanical aspects of the insulators.

[4]The numbers in brackets correspond to those in the bibliography in Annex A.

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3.3.1 routine test load (RTL): The load applied to all assembled insulators during a routine mechanical load test. (ANSI C29.11-1989).[5]

3.3.2 specified mechanical load (SML): A load specified by the manufacturer that has to be verified during the mechanical load test. (ANSI C29.11-1989).

3.3.3 tracking: Irreversible deterioration of surface material from the formation of conductive carbonized paths.

3.3.4 treeing: Irreversible internal deterioration by the formation of conductive or nonconductive filamentary channels.

4. Service experience of composite insulators

The service experience with composite insulators has generally been positive. Polymeric insulators have been utilized on both transmission and distribution systems. Some have been in service for more than 25 years. Many more have been used on distribution systems than on transmission networks. However, there has been little documentation of distribution-class service experience. Service experience with transmission-class composite insulators has been summarized in three surveys. Two of these, one conducted by CIGRE[6] and the other by EPRI, reported on experience with use of composite insulators on ac systems. Both of these were published in 1989. The third, carried out by CIGRE, reported experience with dc applications. The results of that survey were published in 1994. The conclusions of these surveys are summarized in 4.1. It should be noted that in the case of ac applications, the information is dated; however, it represents the only currently available comprehensive base of information.

4.1 Service experience with alternating current (ac) systems

The EPRI survey indicated that in the United States composite insulators are used over a wide range of voltages. They are applied to different structures and over the entire spectrum of contamination levels. Overall the operational experience was considered good in 78% of applications, acceptable in 18%, and poor in 4%. Of the failures reported, approximately 17% were identified as electrical. A similar number were identified as mechanical. Over 60% of the reported failures were classified as general deterioration, and about 2% were a consequence of gunshot. The electrical failures included flashover due to surface contamination, bird droppings, salt spray, and icing. The reported mechanical failures included rod damage due to excessive torsional loading encountered during handling and installation, and several occurrences of stress corrosion induced fracture (commonly referred to as brittle fracture). Detailed information on stress corrosion induced fracture is given in CIGRE WG 22-03 [B5].

The CIGRE survey included data from the EPRI survey wherever possible. It indicated that the data covered approximately 50% of the transmission class insulators manufactured up to 1986, and that most of the insulators used worldwide were installed in North America. The results showed that, in the case of suspension, units 53% were installed at system voltages below 200 kV, 27% were installed at system voltages of 200 kV and above but less than 300 kV, 16% at system voltages between 300 kV and above but less than 500 kV, and 4% at system voltages of 500 kV and above. For tension insulators, 54% were installed at system voltages below 200 kV, 16% were installed at system voltages of 200 kV and above but less than 300 kV, 26% at system voltages of 300 kV and above but less than 500 kV, and 3% at system voltages of 500 kV and above. In the case of line posts, applications at system voltages below 200 kV account for 79% of the installed units, applications in the range of 200 kV and up but less than 300 kV account for 20% of the

[5]Information on references can be found in Clause 2.

[6]CIGRE Publications can be purchased in paper form from mailto://sales-meetings@cigre.org or in electronic form directly from http://www.cigre.org.

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installed units, applications in the range of 300 kV and up but less than 500 kV represent 1% of the installed units, and applications at system voltages of 500 kV and above represent only 0.1% of the installed units. The report also presents details on special applications of composite insulators from the viewpoint of what proportions are installed under what type of operating environments, as well as failure statistics and descriptions. The report contains the following conclusions. Most of the reported failures involved insulators that were produced prior to or during the early 1980s. Since that time many manufacturers have modified and improved the design and production quality control of their insulators. Users may also have modified their criteria for the utilization of composite insulators. When the definitions of a failure in the CIGRE and EPRI surveys are harmonized, the number of failures (i.e., the operational experience quoted in the preceding paragraph) agrees with the EPRI results. It further concludes that in North America the production and therefore presumably the use of composite insulators has very much increased since the survey was carried out.

Detailed information on the results of these surveys can be found in CIGRE WG 22-03 [B4], and Schneider, Hall, and Karady [B17], which detail the surveys and their results.

4.2 Service experience with direct current (dc) systems

The experience with dc applications is far more limited than in the case of ac. The majority of the 800 insulators covered in the CIGRE survey were installed on systems operated at +/– 400 kV and above. The conclusions suggest that, in general, the experience with composite insulators on dc systems was good at the time the survey was carried out. Details of the findings of this survey can be found in CIGRE WG 22-03 [B6].

5. Polymer aging and long-term endurance of high-voltage (HV) composite insulators

High-voltage (HV) insulators fulfill both mechanical and electrical functions in power systems. The performance of an insulator is dependent on its ability to endure the long-term mechanical and electrical stresses imposed upon it during its service period. The mechanical stresses are caused by tension, compression, bending, or torsion loads, which may be static or dynamic. The electrical stresses are caused by steady state power frequency or dc voltages and occasional transient overvoltages, which may produce discharges or arcing.

A composite insulator is designed to withstand specified service stresses for the lifetime of the unit. The fibreglass core and the metallic end fittings are integral to the mechanical function while the housing (sheathing and weathersheds) provides the required electrical leakage distance and also protects the rod. Both the rod and the housing contain polymers and inorganic materials. Aging of the polymers in the insulator system may effect the insulator's functional properties. Therefore, it is vitally important to evaluate the effects of material aging on the performance of the insulator system.

Generally, it has been established that it is not possible to predict insulation performance from polymer composition. Polymers are used in many forms, and changes in the properties of the polymer composition with aging may or may not be relevant to the functions and design of the insulator system. All polymers will age under long-term exposure to sunlight, weathering, contamination, corona dry-band discharge activity, and temperature. However, in the case of composite insulators, aging is only important if the material changes cause a significant reduction in the unit's performance capability or service life.

In the evaluation of the aging of composite insulators, it is necessary to analyze insulator functions and determine system failure mechanisms. In the HV insulator case, this means

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a) Determine dominant insulator failure mechanisms through a consideration of materials, processing, environment, and stress on the insulator.

b) Determine which changes in material properties are likely to result in a reduction of the insulator's in-service performance.

5.1 Mechanical aging

Continued exposure to high mechanical stress may cause permanent changes in the structure and properties of the fibreglass reinforced polymer rod. These changes can be characterized as mechanical aging occurring when the applied load is above the "damage limit" of the insulator system.

The long-term performance above the damage limit can be described as a "creep" phenomenon, although the mechanisms involved are completely different from the known creep mechanisms found in metals. Attached to the notion of creep (permanent deformation under stress, time, and temperature) and the associated "damage" to the fibre reinforced resin rod, there is the notion of long-term performance.

At very high loads on a unidirectional resin bonded glassfibre composite rod, a stress rupture phenomenon may occur and under constant load, a delayed rupture can take place. The time to failure depends upon the load. The residual strength of the composite material remains very high until the instant of failure. The long-term behavior of an insulator depends on the microscopic behavior of glassfibre and resin.

Load-time curves for different composite insulator designs subjected to different forms of loading are obtained through years of controlled tests. In fact, some units have been kept under relatively high loads for several years in order to plot the time load curve. The design and damage limits for an insulator type are based on these long-term endurance tests.

The long-term performance of the rod-end fitting assembly is also critically dependent on the continued protection provided by the housing. The aging of the housing must never result in direct exposure of the rod to the environment since this will change the mechanical behavior of the rod. Accordingly, aging tests conducted to evaluate changes in mechanical behavior require testing of complete systems including the housing, the rod-fitting assembly, and the sealing system.

5.2 Electrical aging

Polymer aging under electrical stress in outdoor conditions, may cause the following changes in the external housing of an insulator:

a) Surface oxidation and chemical reactions, which change the polymer surface and volume structure.

b) Surface crazing and cracking due to the effects of radiation, temperature, ozone, and water.

c) Erosion or tracking caused by surface discharge activity.

The voltage distribution along a polymer insulator exposed to wet polluted conditions is dependent on the insulator surface conductance. Therefore, changes in the surface resistance can be related to the voltage withstand capability of the insulator. Changes in the chemical composition and structure of the surface of the housing materials may affect the surface resistance of HV insulators under wet and polluted conditions. This has been demonstrated by service experience and testing that has shown that variations in these surface properties of the housing affect the leakage currents and withstand voltage capabilities of HV insulators.

Material studies have shown that the surfaces of polymers are relatively mobile in comparison to porcelain and glass. Polymer molecules have much greater freedom for rearranging in the bulk or at the surface. The relaxation time for a polymer surface to establish equilibrium with a new environment varies dramatically between different polymers and within generic polymer systems. The polymer surface also has the ability to

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interact with pollutants and reduce the conductance of the pollution layer. This has a significant effect on the contamination behavior of composite insulators.

5.3 Insulator design and aging

The design and application of composite insulators in Transmission and Distribution (T&D) systems must be based on long-term performance and endurance data and/or experience. Since there are no present standards for such evaluation, the manufacturer and the user must work together in the reliability assessment of the insulator design.

5.4 Aging tests

Long-term characteristics are established by service experience or accelerated aging tests. Laboratory accelerated aging tests are conducted with the insulator or model under electrical and/or mechanical stresses and subjected to cyclic exposure to environmental conditions such as:

- Simulated solar radiation
- Artificial rain
- Dry heat
- Damp heat (near saturation)
- High humidity at room temperature (saturation must be obtained)
- Pollution such as salt fog

The condition of the test samples is monitored by leakage current measurements and by periodic withstand tests to establish changes in the performance capability of the insulator system under test.

6. Mechanical considerations for suspension insulators

For additional information, see the bibliography given in Annex A.

6.1 Tension ratings

Two major standards bodies, the International Electrotechnical Commission (IEC) and the American National Standards Institute (ANSI), define the test methods to be used in demonstrating the adequacy of tension ratings. The ratings themselves are assigned by each manufacturer.

6.1.1 Sample tests

The IEC and ANSI test methods are essentially the same. The procedure requires that the sample insulators be subjected to a tensile load that is increased rapidly but smoothly from zero to 75% of the Specified Mechanical Load (SML) and then gradually up to 100% of the SML in a time between 30 and 90 seconds. If 100% of the SML is reached in less than 90 seconds, the load is maintained at SML for the remainder of the 90 seconds. The insulator is considered to have passed if no failure occurs. Following this 90-second period, ANSI mandates (while IEC leaves as optional) that the load be increased until failure occurs. The load at which failure occurs is recorded and used to justify the manufacturer's choice of SML.

6.1.2 Routine tests

The IEC and ANSI definitions are identical. The Routine Test Load (RTL) is a rating equal to 50% of the SML. The actual routine load applied to each insulator shall be at least the RTL and shall be held for at least

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10 seconds. If the actual routine load applied to each insulator exceeds the RTL, it should be established that the routine tests are not causing damage to the insulators.

NOTE— Ratings for composite insulators closely parallel those for ceramic insulators. Compliance with the Mechanical and Electrical (M&E) rating for ceramic insulators is demonstrated by failing insulators and statistically demonstrating the required margin between the rating and the ultimate strength. Compliance with the withstand rating for composite insulators is demonstrated by a withstand test for 90 seconds at the rating.

Both ceramic and composite insulators must withstand a routine test of at least 50% of the tension rating; ceramic insulators for 3 seconds, composite insulators for 10 seconds.

Both ceramic and composite insulators may be used continuously at loads up to the RTL.

6.2 Compression loads

Suspension insulators do not ordinarily have compression ratings. Not all designs have the same compression capability. On some types of suspension insulators, the grip of the metal end fitting to the core has a very low compression load-carrying ability. Generally, for very long insulators, the compression ratings are limited by buckling. A large variation in compressive strength can be found depending upon how the ends are restrained.

6.3 Bending

Suspension insulators normally do not have bending ratings. In some applications, for example, when used as phase-to-phase spacers, suspension insulators will experience bending loads. In this application, it will be necessary to obtain the bending capabilities of the specific insulator from the manufacturer because not all types of tension insulators have the same bending capabilities.

6.4 Torsion

The torsion strength of a composite suspension insulator is determined in a manner similar to that used to determine the torsion strength of a porcelain cap and pin or post type apparatus insulator. The only difference between the two is that composite insulators are examined following the test to determine if any damage has occurred, while porcelain units are judged on a break or no-break basis. Composite suspension insulators have been damaged in dead-end applications by excessive twisting. The torsion capability of suspension insulators depends on the combined torsional strength of the rod and on the method of attaching the end fittings to the core. There is a wide variation in the torsional load capability of various insulators. Caution is advised in using single insulators to dead-end long conductor spans as the torsional limits of composite insulators can definitely be exceeded. Such situations can be remedied through the use of parallel units or stress relieving hardware.

6.5 Combined loads

Suspension insulators do not carry combined ratings. For applications such as phase-to-phase or V-string insulators where combined loads may occur it is advisable to consult with the manufacturer.

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7. Mechanical considerations for line post insulators

7.1 Mechanical rating criterion

Maximum Design Cantilever Load (MDCL) is a mechanical characteristic by which Composite Line Post Insulators (CLPI) are rated. This is the maximum cantilever load that the insulator is designed to withstand continuously throughout its service life. At this level of load, which generally represents 40% to 50% of failing load (as defined by failure data provided by manufacturers), there will be no reduction in strength due to mechanical damage of the insulator's components. At this point in time, universally accepted definitions of cantilever load characteristics, including failure and failing load, have not been agreed upon and are under consideration by ANSI and IEC.

7.2 Tension loads

Tensile strength of composite line post insulators is dependent on the mechanical characteristics of the end fittings, and on those of the core-to-end fitting interfaces.

7.3 Compression loads

Compression loads on line post insulators do not usually result in damaging stresses until buckling occurs. Generally, elastic buckling of long posts, while not desirable, is not damaging. However, for further information on this, the manufacturer should be consulted.

7.4 Torsion loads

Some designs of line post insulators may have low torsional capability. In this event, cracking of the fibreglass rod or permanent rotation of the end fittings can occur by twisting. The manufacturer should be consulted to determine the torsional capability of a given insulator.

7.5 Combined loads

Actual line loads are rarely single loads. Usually, they are a combination of loads. When comparing actual mechanical load conditions with composite line post mechanical strength ratings, it must be recognized that vertical transverse and longitudinal loads each contribute to the total bending moment on the insulator, and therefore to total cantilever load. To aid designers in determining how the combined mechanical loads in an intended application compare with the cantilever strength capability of a particular composite line post insulator, some manufacturers provide application curves and instruction on their proper use. At this point in time, universally accepted definitions of cantilever load characteristics have not been agreed upon and are under consideration by ANSI and IEC.

8. Interchangeability of insulators

In this guide, interchangeability refers to the ability to interchange standard porcelain or glass insulators with composite insulators. Three aspects of interchangeability need to be considered, namely, mechanical, electrical, and dimensional. For additional information on insulators of the distribution class, see the bibliography given in Annex A.

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8.1 Suspension insulators

8.1.1 Mechanical

Suspension insulators of a given SML rating, rated in accordance with ANSI or IEC standards are mechanically directly interchangeable with porcelain or glass suspension insulators of the same M&E rating. Such insulators have a SML specified by the manufacturer and verified during the mechanical load test described in Section 9 of ANSI C29.11-1989, or Section 7 of IEC 61109 (1992-03). The maximum working load recommended by manufacturers is 50% of the SML rating.

NOTE— Caution is advised since at one time some composite suspension insulators were rated by the Maximum Design Load (MDL) method. In such cases the MDL was defined as the maximum mechanical load that the insulator is designed to withstand continuously for its service life.

8.1.2 Electrical

When replacing conventional porcelain or glass suspension insulators with composite insulators in existing installations, not all characteristics will remain the same. Insulators having the same dry arc distance will have similar critical impulse flashover. Insulators having the same section length may not have the same electrical characteristics since the length of the end fittings used on composite insulators may result in a reduced dry arc distance. Where grading rings are used, the dry arc distance is usually the distance between rings. For the same dry arc distance, the wet flashover and short-term contamination flashover are greater than for conventional porcelain or glass insulators. For further information on contamination performance, refer to Clause 11.

It should be noted that composite insulators are not required to be electrically proof tested. This absence of a required factory proof test should be considered if they are to be installed using live-line techniques.

8.1.3 Dimensional

Composite insulators are available with a wide variety of metal end fittings, including oval eyes, ANSI and IEC balls and sockets, and tongue and clevis fittings. The oval eye and y-clevis are the only fittings that are not common to conventional porcelain or glass insulators. These fittings are normally used for insulator attachment to towers and yokes.

8.2 Post insulators

8.2.1 Mechanical

Composite post insulators are available in strengths lower than equal to or exceeding those of their porcelain counterparts, and are normally directly interchangeable.

However, it is necessary that caution be used due to differences in rating systems. Porcelain posts rated in accordance with ANSI standards are rated at a level indicative of their average ultimate strength. The maximum working load recommended by manufacturers is 40% of rating.

Composite post insulators are rated either by their ultimate strength or by the Maximum Design Withstand Load (MDWL), which is the maximum cantilever load in service that the insulator is designed to carry. The latter rating may be fully utilized.

Ultimate strength is normally more than twice the MDWL. It is important to be sure which rating system is being used.

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Also, the combined tension, compression, vertical, and longitudinal loads must be considered for composite insulators. Deflection characteristics may be a critical consideration for station post application.

8.2.2 Electrical (see also8.1.2)

8.2.2.1 Line posts

Composite line post insulators can be obtained with electrical characteristics the same, or better than those of the porcelain posts they are intended to replace; thus, there are no electrical interchangeability problems known. For contamination performance, refer to Clause 11.

8.2.2.2 Station posts

Composite station post insulators having the same section length as porcelain station posts may not have the same electrical characteristics. Manufacturers should be contacted for information on interchangeability. For contamination performance, refer to Clause 11.

8.2.3 Dimensional (see also 8.1.3)

8.2.3.1 Line posts

Small changes in length are usually not critical for line post insulator applications. Therefore, it is common practice to adjust the line post dimensions to obtain the proper characteristics for direct interchangeability based on electrical requirements. Mounting dimensions should be carefully reviewed.

8.2.3.2 Station post

Composite station post insulators are normally available as direct substitutes for the porcelain posts they are intended to replace. Direct interchangeability is usually possible, but the mounting dimensions should be carefully reviewed.

9. Grading devices

Grading devices are used to reshape the electric field at the insulator ends. They reduce the electrical stress in the bulk and on the surface of the insulator, and in the surrounding air. Grading devices normally take the form of metal rings, which are designed so as to prevent corona on the insulator assembly under fair weather conditions. Corona can be the source of several problems detrimental to the performance of the insulators and to the insulators themselves. Corona on composite insulators results in the generation of radio noise, and can cause deterioration of the insulating material itself. Presence of corona can result in corona cutting and deterioration or loss of non-ceramic insulating materials. Compaction of lines may make the use of corona rings on composite insulators necessary at lower voltage levels than those suggested in 9.1 through 9.4. Larger corona rings may be necessary for insulators used in areas of heavy contamination.

9.1 Suspension insulators

Grading devices are usually required on both ends of suspension insulators at voltages above 345 kV. In the range of voltages from 230 to 345 kV, inclusive, a grading device is required at the line end. For voltage ratings below 230 kV, the application of grading rings or other grading devices may or may not be necessary. Recommendations as to the necessity of their installation should be obtained from the manufacturer.

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9.2 Dead-end insulators

Grading devices are usually required on both ends of dead-end insulators at voltages above 345 kV. In the range of voltages from 230 to 345 kV, inclusive, a grading device is required at the line end. For voltage ratings below 230 kV, the application of grading rings or other grading devices may or may not be necessary. Recommendations as to the necessity of their installation should be obtained from the manufacturer.

9.3 Phase-to-Phase insulators

Grading devices are recommended on both ends of phase-to-phase spacers when used at or above 161 kV. For voltage ratings below 161 kV, the application of grading rings or other grading devices may or may not be necessary. Recommendations as to the necessity of their installation should be obtained from the manufacturer.

9.4 Post insulators

Grading devices are required on post insulators above 230 kV. A grading device is required on the suspension support insulator of both the horizontal vee and the braced post operating at 230 kV and above. A single grading ring shielding both the positioning and the suspension support insulators can be used. For voltage ratings of 230 kV and below, the application of grading rings or other grading devices may or may not be necessary on post insulators. Research is currently being performed to investigate which non-supported post configurations require grading at 230 kV and below. In the interim, recommendations as to the necessity of their installation should be obtained from the manufacturer.

10. Maintenance

10.1 Insulator cleaning

Composite insulators may be dry-cleaned with air-blast abrasive material or washed according to the methods referenced in the bibliography given in Annex A. Either may be done energized or deenergized. Low-pressure water spray washing of composite insulators has been done successfully. Not all insulators can withstand the force of high-pressure (3 to 7 Mpa) washing.[7] Water may penetrate beneath the weathersheds of some designs. It is advisable to consult the manufacturer to determine acceptable cleaning methods.

10.2 Greasing

Experience has shown that channelled arcing in a greased composite insulator may lead to tracking of the insulator. Therefore, greasing of composite insulators is not advisable. Additional information is referenced in the bibliography given in Annex A.

10.3 Damaged insulators

The practice of applying composite insulators in outlying areas where shooting vandalism is a problem has been adopted by many utilities. Damage to composite insulators, particularly from small arms ammunition, may not always be easily detected visually. When such damage is detected, the damaged insulators should be replaced as soon as practical, especially if embedded metal is found in the core of the insulator. A few holes through only the sheds will have little or no adverse effect on the performance of the insulator, however

[7] 1 MPa=0.14 1bf/in^2.

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puncture of the sheath will result in the ingress of moisture into the core and imminent failure of the insulator.

11. General

11.1 Contamination

In laboratory tests and field installations, composite insulators have been shown to exhibit short-term resistance to contamination flashover that is superior to that of conventional porcelain or glass insulators. This is primarily attributed to the significant difference in the geometry and surface wettability of polymer and porcelain materials. However, it is generally felt that the contamination flashover performance of composite insulators deteriorates to some degree with surface aging. This surface aging can be accelerated by exposure to contaminated conditions. The extent of this aging and its effect on the insulator's contamination flashover performance is thought to be dependent on the shed material used, as different materials exhibit different ability to maintain and/or recover their original high degree of water repellency under long-term service conditions.

Experience in areas with heavy airborne pollutants, such as phosphate, cement, pulp, lime, and ash, has shown that composite insulators provide significantly better flashover performance than porcelain or glass. Because of this, composite insulators have worked satisfactorily in some areas where porcelain or glass units have been unable to provide satisfactory service. Although composite insulators have resolved numerous contamination flashover problems, in very severe environments, excessive deposits of contaminants may cause localized activity leading to damage on composite insulators. When using composite insulators near manufacturing plants where the insulators may be totally engulfed by the contaminant, prior performance of similar composite insulators in similar environments should be reviewed. Failures have occurred in phosphate, cement, pulp, and lime processing plants, and damage is a distinct possibility in any facility that produces heavy airborne pollutants. Therefore, when composite insulators are installed in a severe environment, a periodic inspection program is advised to ensure that the insulators remain in good condition. Since composite insulators may retain more contaminants than their porcelain or glass counterparts without affecting performance, the aim of such an inspection program should be to detect actual damage to the insulators rather than levels of contamination.

11.2 Leakage distance requirements

Composite insulators have normally been applied with leakage distances equal to or greater than those prescribed for ceramic units. Since in some cases, composite insulators have performed better than porcelain units having the same leakage distance, it appears logical that in some environments equivalent contamination flashover performance can be attained with the use of composite insulators having shorter leakage distance. The margin by which polymeric insulator contamination flashover performance exceeds that of porcelain is dependent on the design of the insulator and on the material from which the insulator housing is composed. Materials having long-term water repellency provide a larger margin than those that do not. Conclusive data describing long-term experience with reduced leakage composite insulators are currently not available. While practice indicates that reduced leakage composite insulators can be successfully utilized in areas that are clean or characterized by light levels of contamination, there is concern that use of reduced leakage insulators in heavily contaminated areas may result in increased leakage current and dry band arcing, thereby shortening the insulators' service life.

11.3 Icing

Experience in icing environments is somewhat scarce and conflicting, and laboratory test data are limited. Under icing conditions, the best electrical performance of both ceramic and non-ceramic insulators is

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normally obtained in V-string configurations. Additional insulation levels, larger spacing between weathersheds, or varying weathershed diameter have proven effective in reducing icing problems. Additional information may be obtained from references given in the bibliography given in Annex A.

11.4 Temperature limits

Composite insulators are in service in the hottest and coldest of climates with no unusual effects due to temperature extremes. Manufacturers have generally agreed to a range of –50 °C to +50 °C.

11.5 Chemical environment

A variety of different materials are used in the various types of composite insulators. In some special applications, such as diesel railways, these materials may be subject to attack from hydrocarbon vapors or other chemicals. Damage to insulator weathersheds has occurred when insulators have been left in contact with wood poles treated with preservatives. In some chemical environments, certain weathershed materials may experience physical changes such as swelling or embrittlement. As discussed in 11.1, an inspection program should be put into place when any type insulator is applied in chemical environments. Insulator manufacturers should be consulted for specific recommendations.

11.6 Power arc damage

When a high-current fault is struck across the ends of an insulator, the mechanical integrity of the insulator may be adversely affected by heating and erosion of the metal end fitting to which the arc roots attach. The degree of damage to the end fittings depends on the insulator design and materials coupled with the magnitude and duration of the current. In some instances, metal-grading rings capable of withstanding a power arc can provide additional protection to the insulator end fittings from power arc damage. Such grading rings must be appropriately designed and properly attached to the insulator end fittings. Comparative tests on several designs are referenced in the bibliography given in Annex A. Possible scenarios that will result in eventual damage to the insulator following the occurrence of a power arc include rod exposure at the metal end fitting and/or corona damage from corona generated at metal surfaces that have been damaged during the power arc.

12. Handling

Composite insulators have different physical dimensions and characteristics from their ceramic counterparts. A direct consequence of this is that the handling requirements for composite insulators are different from those routinely used for ceramic units. Sub-clause 12.1 through 12.3 describes in general terms those handling requirements.

12.1 Packaging

Composite insulators will normally be bulk packed in a wood or corrugated cardboard carton. The number of units per pack will usually be determined by the size of the units or order size. Insulators may also be individually packed within the pack in tubes or sleeves. The actual packing method will be determined by the manufacturer; thus, special requirements should be discussed.

12.2 Removal from packing

Composite insulators have an elastomeric housing. Therefore, any means of removal from the packaging that involves cutting of packing materials should be done in such a manner that the elastomeric housing of the

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insulator is not cut. Care must be taken and each insulator should be inspected for damage after being removed from the packing material.

12.3 Handling, transportation, and installation

Composite insulators are much lighter than the corresponding strings of porcelain or glass insulators. This makes them much easier to transport and install. However, because most composite insulators are made of less durable fibreglass and elastomeric materials, they must be handled with care at all times. They can be easily torn by sharp objects or tools, and they can be damaged when transported unprotected on the overhead racks of crew trucks. A single cut or tear that exposes the fibreglass rod to moisture will eventually result in the mechanical failure of the insulator. During line construction, when ground assembly is used, the insulators should be tied up to cross arms or structures to ensure that they will not be subjected to compressive or bending loads during structure erection. Compressive loads should also be avoided during conductor stringing at uplift locations. Construction methods that subject a composite insulator to a force or load that it would not see in service should not be used.

Experience has shown that composite insulators can be damaged by rodents during storage. Appropriate precautions should be taken to prevent the possibility of this occurring.

Some guidelines, which when followed will insure that composite insulators are not damaged during handling, transportation, and installation include the following:

— General care in handling.
— Insulators should be stored and transported in their shipping crates. PVC tubes with ventilated end caps are a good substitute for original packing.
— Units should be carried or lifted by their end fittings.
— Insulators should be thoroughly inspected for cuts or abrasions before installation.
— Shackles and other such hardware should be used during installation to prevent binding or bending.

The following list contains cautions against specific work practices, that may result in damage to composite insulators.

— Insulators should not be stacked on one another (end fitting of one can cut into the elastomeric housing of another).
— Insulators should not be lifted by the elastomeric sheds unless carefully done by hand. Slings should never be placed over the sheds.
— Insulators should not be subject to any excess bending.
— Insulators should not be stepped on or walked on.
— Insulators should not be climbed on after installation.

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Annex A

(informative)

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