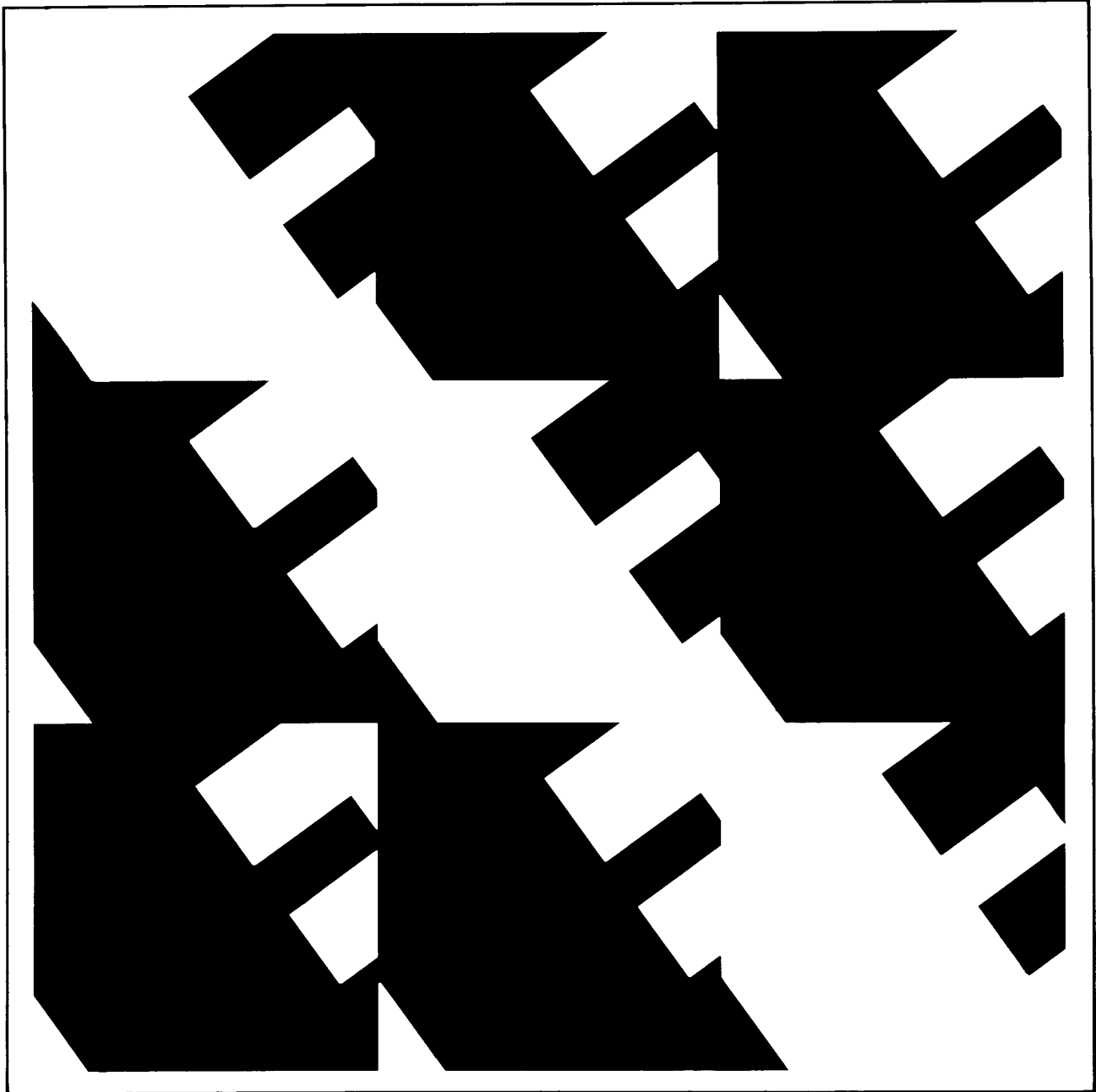


IEEE Guide for Field Testing Power Apparatus Insulation



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Foreword

(This Foreword is not a part of IEEE Std 62-1978, Guide for Field Testing Power Apparatus Insulation.)

Factory tests assure the initial quality and condition of power apparatus insulation. During shipment, installation, and service, the apparatus is subject to influences that may affect the insulation and shorten its useful life. As a result, apparatus insulation is tested in the field from time to time to determine its suitability for continued service and to detect deterioration which often can be checked or corrected by suitable maintenance procedures.

The variety of test methods and equipment used for the assessment of insulation quality necessitates the restriction of this guide to a general description of the more commonly used methods. An attempt has been made to supply sufficient information to identify those tests more applicable to a given situation and to provide references to a more detailed coverage.

This guide was first published in April 1958 as AIEE Std 62, Recommended Guide for Making Dielectric Measurements in the Field. This revision is the first since that time. Withstand tests have been given greater coverage and the material on measurement of insulation characteristics reflects experience gained in the intervening years.

This revision has been prepared by a Working Group under the sponsorship of the High Voltage Testing Techniques Subcommittee of the IEEE Power Systems Instrumentation and Measurements Committee. The assistance of A. F. Rohlf, Chairman, and other members of the High Voltage Testing Techniques Subcommittee, is gratefully acknowledged.

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IEEE Guide for Field Testing Power Apparatus Insulation

1. Scope

This guide discusses the significance of various types of tests commonly employed to evaluate the insulation of power apparatus in the field, where environmental conditions cannot readily be controlled; the equipment and techniques required for each type of test; problems peculiar to field testing, and methods of dealing with these problems; and the application of field tests to specific types of power apparatus.

2. Safety

2.1 Personnel

2.1.1 Hazards. Insulation tests in the field can present a hazard to personnel unless suitable precautions are taken. Apparatus or circuits to be made available to test personnel must be disconnected from the power system. Typical safety procedures call for a visual check of the disconnection or, when this is not possible, a check with a voltage indicator. Grounds are then applied. Personnel are usually instructed to treat all ungrounded apparatus as energized.

2.1.1 Ground Connection. Grounds may be removed to permit application of test voltage. When feasible, it is preferable to retain the ground connection during the tests and to provide between the ground and the apparatus under test a second disconnection of sufficient clearance for the test voltage (see 6.8.3.2).

2.1.3 Precautions. When the test voltage is over a few volts, precautions should be taken to prevent personnel from contacting the energized circuit. An observer may be stationed to warn approaching personnel and may be supplied with means to deenergize the circuit. The means may include a switch to shut off the power source and, particularly in case of a di-

rect test voltage, provisions for grounding the circuit until all stored charges are dissipated.

2.1.4 Warning Signs and Barriers. The test area may be marked off with signs and easily visible tape. Warning signs should conform to the requirements of governing bodies such as the Occupational Safety and Health Administration (OSHA) in the United States.

2.2 Apparatus

2.2.1 Consequences of Failure. When the test voltage to be applied to apparatus insulation exceeds the normal operating value, there exists the possibility of failure under test. Before applying the test, consideration should be given to the time, material, and labor required for a possible repair. If failure could result in fire, fire-fighting equipment should be available.

2.2.2 Overvoltage. In the conduct of high-voltage tests the voltage may accidentally exceed the desired maximum. A sphere gap, adjusted to spark over at a voltage slightly above the desired maximum, may be connected across the voltage source. By selecting the proper value of series resistor, the gap may be used to provide a warning signal, to inhibit further rise in the test voltage, or to activate an overcurrent circuit breaker in the power supply circuit.

2.2.3 Graded Insulation. When an alternating test voltage is applied to a short-circuited winding, or when a direct test voltage is used, the insulation of the entire winding is subject to this test voltage. When the insulation level of the winding is graded from one end to the other, the magnitude of the applied test voltage should correspond to the lowest insulation level.

3. Withstand Voltage Tests

3.1 Description

3.1.1 General. A withstand voltage test sub-

jects an insulation for a restricted period of time to a voltage stress greater than that encountered under normal service conditions. The magnitude of the test voltage used in the field is generally based on the factory acceptance test voltage, reduced by a factor to allow for the effects of transportation, installation, and in-service degradation.

3.1.2 Type of Voltage. The voltage specified for a withstand test may be alternating at power frequency or some other frequency, may be direct (having a specified polarity in respect to ground), may be a pulse having a specified polarity and wave shape, or may be a pulse-generated transient.

3.1.3 Duration of Voltage Application. For alternating or direct test voltages, the duration of application is specified, commonly 1 min after the desired test value has been reached. Voltage applications are made at a prescribed rate or in scheduled increments.

3.1.4 Impulse Voltage. For an impulse, the voltage-time relation (wave shape) is specified. A standard lightning impulse wave is denoted by two figures: 1.2/50. The first figure is the virtual rise time in microseconds of the pulse; the second is the virtual time to half value in microseconds.

3.1.5 Pulse-Generated Voltage. For pulse-generated transients, the peak voltage and oscillation frequency are specified. If repetitive, the repetition rate is also specified.

3.2 Significance. The withstand voltage test is a demonstration that an insulation can withstand a specified overvoltage for a specified length of time and is essentially a go-no-go type of test. Successful completion of the test gives some assurance that no gross defect is present in the insulation structure. However, the ability of a withstand voltage test to expose incipient faults is less certain. For this reason the test is often supplemented by measurements of insulation characteristics, made during or at the completion of the withstand test.

3.3 Elementary Theory

3.3.1 Intrinsic Dielectric Strength. As opposed to a conductor, in which electrons move with little restriction, an insulator is a material in which the electrons are tightly bound to atoms or molecules. When an insulator is subjected to a moderate potential gradient, some electrons may be pulled free from their bonds, but are recaptured in collision with a neighbor-

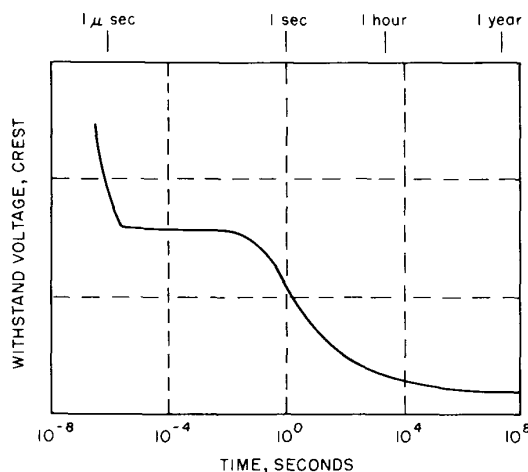
ing atom or molecule. When the gradient is strengthened beyond a critical value, called the intrinsic dielectric strength of the material, collisions occur with sufficient impact to free more electrons than are captured, and disruptive breakdown follows.

3.3.2 Practical Dielectric Strength. Most insulating materials are not entirely homogeneous and so contain some regions having less than average dielectric strengths. Under test there will be a tendency for breakdown to occur in a path which includes regions of lower dielectric strength. The actual dielectric strength of an insulating material in practice is usually substantially lower than its intrinsic strength.

3.3.3 Time and Temperature Effects. Continued application of a voltage gradient below the value required to cause immediate breakdown will cause temperature rises in local weak regions. The temperature rise further reduces the dielectric strength of these regions, and consequently the overall dielectric strength of the material, and may result in eventual failure without further increase in the applied voltage. As an example of the time dependence in withstand testing, Fig 1 illustrates the general behavior of oil-impregnated pressboard in terms of withstand voltage versus time of voltage application.

Materials which are normally lossy under voltage stress are subject to destruction from

Fig 1
Effect of Time on
Withstand Voltage



thermal runaway. Runaway occurs when the applied stress is high enough to generate more heat in the material than can be dissipated into the environment. The voltage at which thermal runaway occurs is therefore not only a function of the material but also of the effectiveness of provisions for dissipating the generated heat.

3.4 Comparison of Tests

3.4.1 Power-Frequency Withstand Test. A power-frequency withstand test is generally considered to subject the insulation under test to a stress pattern most closely resembling that occurring in service. The disadvantages of the power-frequency test are possible damage to corona-sensitive insulation and the massive equipment necessary to energize high-capacitance specimens. The latter disadvantage may be partially alleviated by the use of resonant methods.

3.4.2 Direct-Voltage Withstand Test. The direct-voltage withstand method requires relatively light-weight equipment. Partial discharge damage is less than with power-frequency tests. There is the possibility, under certain conditions, of predicting and thus avoiding breakdown of weak insulation. The prediction procedure involves the application of the test voltage in steps in accordance with a predetermined schedule, with a measurement of current or resistance made at each step.

A disadvantage of the direct-voltage withstand test for a composite insulation system designed to operate under alternating-voltage stress is that the test may not produce a normal stress pattern in the insulation. With time of voltage application, the direct-voltage stress pattern tends to conform more to the resistive characteristics of a composite system than to the combined resistive and capacitive characteristics which determine the alternating-voltage stress pattern. This disadvantage is particularly apparent for systems where resistive-capacitive stress grading is employed, since with an applied direct voltage the stress will not be graded in the designed manner. Prolonged direct-voltage withstand tests are not recommended for oil-immersed equipment because contaminating particles in the oil tend to line up and form a breakdown path.

3.4.3 Very Low Frequency Withstand Tests. Withstand tests on high-capacitance specimens may be made using an alternating test

voltage of very low frequency (for example, 0.1 Hz) to obtain the advantage of reduced weight and reduced partial discharge damage while providing an approximately normal stress pattern. The weight of very low frequency test equipment is less than the usual power-frequency test equipment and approximately the same as power-frequency equipment when resonant methods are employed.

3.4.4 High-Frequency Withstand Test. Withstand test voltages at higher than normal frequency are used for testing the insulation of windings on magnetic cores, as in transformers and reactors. The higher frequency permits an overvoltage to be applied across the winding without the problem of core saturation. This type of test applies overvoltage on turn-to-turn insulation as well as on the insulation between winding and ground.

3.4.5 Impulse Test. Impulse tests may be made on insulation systems subject to voltage surges in service. Such systems include turn-to-turn insulation of coils or windings. Impulse testing of apparatus insulation in the field is usually restricted to low-voltage apparatus because high-voltage impulse generators are not readily portable.

3.5 Environmental Influences. The voltage withstand capability of insulation structures designed for field service is affected to some extent by normal variations in the field environment. Low barometric pressure, surface dirt, and moisture are conditions which tend to lower surface flashover voltages and thus interfere with the conduct of a withstand test. In general, however, the reduction in test voltage levels allowed for field testing is usually sufficient to permit tests to be successfully conducted.

3.6 Test Equipment. Commercial equipment is available for all types of withstand tests. Important specifications which must be considered include:

- (1) Type of voltage output — impulse, direct, alternating (include frequency)
- (2) Voltage range
- (3) Voltage control facilities including rate-of-rise capability
- (4) Power output — real and reactive power capability for ac tests, output current range for dc tests, energy discharge capability for impulse tests

- (5) Power input requirements
- (6) Weight and portability

4. Potential-Distribution Tests

4.1 Description. The potential-distribution test method requires the measurement of potential at or between various locations over an insulating unit. The method is most often applied to the testing of ac transmission line insulators while in service. In the application of this method to a string of suspension insulators, for example, the potential across each insulation may be measured.

4.2 Significance. A normal potential distribution is an indication that the insulating unit is in satisfactory condition. Any section of a unit across which the potential difference is lower than normal is considered to be in questionable condition.

4.3 Equipment

4.3.1 Safety. Safety is a primary requirement for potential-distribution testing devices to be used on energized transmission systems. The device must be so designed that it can be used without the possibility of creating a transmission outage from a short circuit or accidental ground.

4.3.2 High Impedance. A potential-distribution testing device must have high electrical impedance so that its use does not appreciably change an existing potential distribution.

4.3.3 Measurement of Potential. Measurements of potential may be obtained either as a meter reading or as a calibrated sphere-gap setting. The sphere gap is adjusted to the maximum setting at which a continuing discharge or sparking can be obtained. Discharge of the gap is monitored by listening to a telephone receiver in the gap circuit through a highly insulated stethoscope arrangement. A more recent method of monitoring a discharge is through the use of a remote detector responsive to electromagnetic radiations from the discharge.

4.3.4 One-Terminal Device. A one-terminal device has an exposed metallic tip for contacting some conducting part of the insulating unit, that is, cap, pin, or cement layer. The measuring circuit is completed by capacitance to ground but is also influenced by capacitance to nearby energized parts. Interpretation of

results should be made by comparison of readings on similar units with the device similarly positioned, rather than on the absolute measured values.

4.3.5 Two-Terminal Devices. Two-terminal devices permit measuring the potential between two conducting parts of the insulating unit, one of which may be at ground potential. The measuring circuit between the two terminals includes the meter or gap-telephone system (see 4.3.3) and a high-voltage high-impedance element. A resistive element is usually used with a meter system and a capacitive element with a spark-gap system.

4.4 Comparison of Methods. Meter devices are difficult to read under adverse lighting conditions, while spark-gap devices are difficult to hear under noisy conditions. Voltage readings are more easily made with the meter device. The inconvenience of adjusting a gap for each insulator is commonly avoided by establishing a few fixed gap settings and using the setting most applicable to the insulator under test. The insulator passes or fails the test depending on whether or not it supports sufficient voltage to cause the gap to discharge.

4.5 Environmental Influences. The voltage distribution over an insulating unit or structure can be influenced by surface conditions. For comparison purposes voltage distribution tests should be made when surfaces are reasonably clean and dry.

The voltage distribution method may not be reliable for detecting cracks in porcelain insulation after prolonged exposure to low-humidity atmosphere, particularly when the operating voltage stress is low.

5. Partial-Discharge (Corona) Tests

5.1 General. Partial discharges in an insulation system are discharges that do not completely bridge the insulation between conductors. One form of partial discharge is corona, a term which more specifically describes discharges which emanate from a bare conductor into the surrounding air or gas. Of more concern to insulation life are partial discharges which occur in inadvertent gaseous inclusions (cavities) in otherwise solid insulation.

A discharge will occur in a cavity if the