

GUIDING PRINCIPLES **for DIELECTRIC TESTS**

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DIELECTRIC TESTS

51-1 Introduction—The service record of electric equipment depends largely upon the performance of its insulation. Insulation failures result from various combinations of such causes as progressive aging, moisture, mechanical damage, excess temperature, chemical action and abnormal voltage stresses. Commercial tests involving all these factors are impractical. It has long been the practice, however, to test new insulation at a voltage appreciably greater than its rated operating voltage. The dielectric test voltages should be chosen to result in good operating performance and satisfactory life.

The establishment of suitable dielectric test specifications involves consideration of the over-voltages to which equipment is subjected in service, a study of equipment strength and protective methods and a correlation of the dielectric test voltages and the performance of equipment in service.

51-2 Purpose—A statement of the purpose of this report follows from this review of the general problem. It is:

- (1) to present a survey of the overvoltages encountered in service.
- (2) to review existing test values and practices in present standards
- (3) to propose guiding principles for the selection of dielectric test values
- (4) to investigate other types of testing to determine their latent usefulness and the desirability of standardization.

51-3 Scope—This report deals with dielectric tests on completed apparatus. Tests on materials and on components during the course of fabrication usually are left to the discretion of the manufacturer and are not a subject for standardization except as to method and technique. Impulse test values where specified in standards are based on the Basic Impulse Levels and thus are consistent for different equipment. Impulse test conditions and technique are outside the scope. Hence, this report deals mostly with conditions and test values associated with low-frequency dielectric tests.

51-4 Objectives of Insulation Testing—There are four main purposes in making insulation tests

on electric equipment. These are outlined as follows under the headings Design, Routine, Acceptance, and Service Tests.

Design tests are used by the manufacturer to determine the adequacy of equipment design in meeting probable service conditions.

Routine tests are used to detect defects in materials and workmanship in processing the equipment through the factory, as well as, in some cases, checking the equipment design.

Acceptance tests furnish proof to the purchaser that definite insulation specifications have been met.

Service tests are valuable in determining at various periods in the service life of the equipment whether or not it has deteriorated unduly or is in an unsafe condition for continued operation. Service tests may take the form of overvoltage tests, power factor and resistance tests of the insulation, or a check of the voltage gradients in various parts of the equipment. Comparisons are made with similar conditions when the equipment was new or in a known satisfactory state.

The insulation tests considered above are mostly overvoltage tests of power-frequency voltage or impulse voltage types. Just what the severity of these tests should be is a subject on which opinions should be correlated to produce the desired results in a satisfactory and economical way. The test voltage value and time duration of application should be severe enough to insure, without injury to the insulation, that there is a factor of safety for any reasonable operating condition expected. The selection of suitable tests, therefore, requires a knowledge of both expected voltage conditions in service and the volt—time characteristics of the insulation and the completed equipment. Overvoltage tests, which have been made on equipment in the past and have proved reliable in detecting weaknesses of design, materials, manufacture, or other features, should not be arbitrarily reduced in standards without the service proof or other evidence that less severe tests will result in completely satisfactory apparatus.

For many kinds of equipment several types of insulation tests are specified. For example on

transformers, applied low-frequency tests, induced low-frequency tests and impulse tests are made. The impulse test was adopted because the low-frequency tests do not insure impulse strength. The impulse test seeks out weak spots across the winding but may not always adequately test the strength of the insulation to ground throughout the winding. However, a certain amount of coordination should be practical and when impulse and low-frequency tests are made, the question of relative severity and the relative insulation levels to meet each test arises. As the impulse ratios of the multitudinous combinations of insulation used in equipment becomes better understood, adjustments in voltage test values may be made. Desirable objectives are better coordination of test values for different tests on the same equipment with possible elimination of some tests.

51-5 Significance of Insulation Tests—The breakdown voltage of insulation as used in electric equipment is a function of time. Usually the short-time breakdown voltage is several times the rated voltage. Present test voltages are generally two or more times the rated voltage and for many reasons are applied for a limited time usually one minute. Specifically the test shows that the insulation withstands the test voltage for one minute. A successful test also indicates:

1. The insulation will withstand some types of overvoltage of two or more times rated voltage for times up to one minute.
2. The insulation usually will withstand rated voltage for an indefinitely long time.
3. No serious defects in workmanships or materials are present.

The significance of the low-frequency overvoltage test is complicated by many other factors. With laminated insulation, the probability of weak spots or defects completely through the insulation decreases as the total thickness increases. It has been demonstrated that a separation in air of as little as 0.00005 inch may require 1600 volts crest for breakdown, whereas a gap three times as long may break down at 400 volts. It follows that complete punctures of thin insulation in low-voltage equipment may not be detected in the overvoltage test. Higher test voltages may not be completely effective in this respect where thicker insulation is involved. Where possible, test voltages should be selected high enough to disclose a pinhole through the solid insulation between insulated parts.

A limitation of most of the non-destructive tests, such as power factor and insulation resist-

ance, has been the difficulty of establishing a definite relation between test data and dielectric strength. Their main field of usefulness seems to be quality control tests in manufacture and service tests in operation.

51-6 Overvoltages in Service—In establishing voltage tests for various classes of equipment in different voltage levels, test values must be selected. Granted that the test values should be more severe than most service conditions, how much more severe should the test conditions be? It seems logical that test voltages should bear a very direct relationship to the voltages to which the apparatus is subjected in service. The question therefore arises, what are the types and ranges of overvoltages expected in service? These may be divided into three groups:

- (a) System-frequency overvoltages
- (b) Overvoltages due to switching and arcing grounds.
- (c) Lightning overvoltages

(a) System-frequency overvoltages
Overvoltages may be due to overspeeding of generators on loss of load, particularly hydro-generators, or inadvertent contact with circuits of higher voltage resulting from fallen wires or broken poles. A third condition is overvoltages which may exist on unfaulted phases of a 3-phase impedance grounded system when one phase is faulted.

The overvoltages on loss of generator load may have a maximum value of about double normal voltage, but the duration is usually only a few seconds. Voltage regulators are usually applied to limit the maximum voltage and duration of such disturbances.

Overvoltages caused by contact with circuits of a higher voltage cannot, of course, be insulated against as the possible range of overvoltage is too wide to be covered by any practical test. Also the frequency of occurrence is too low to justify protection by overvoltage tests.

The voltages occurring on unfaulted phases of 3-phase systems, however, are of practical importance as many cases are encountered in the useful life of equipment. The magnitude of these voltages depends upon the circuit constants involved.¹ The normal-frequency overvoltage on the unfaulted phase has a maximum value of 1.732 times the normal line-to-ground voltage of the system, depending on the degree of grounding. These overvoltages are also of relatively short duration and the time is controlled by the relay protective system. Times of the order of a few cycles, or a few seconds as a maximum, are the upper limit unless control and isolating equipment fail to function properly.