THE TESTING OF INSULATORS.

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A statement of the requirements for satisfactory insulators and recommendations as to apparatus and methods of carrying on insulator tests.

An electric power transmission cannot be successful unless it is able to deliver uninterrupted power.

Continuous operation, so far as the transmission line is concerned, depends largely upon the effectiveness of the insulator which is employed. Insulators must, therefore, be obtained which will not fail in service and this can only be assured by the thorough testing of each one that goes on the electric lines.

The potential that can be employed safely for the transmission of power is now limited by the pressure the insulators will bear, as transformers that are reliable and not excessive in cost can be built for twice the voltage that any line yet constructed will withstand.

As the distance over which power can be transmitted with a fixed cost of conductor varies with the potential, the length of transmission lines is to a great extent limited by the insulator.

The design of new and improved types of insulators is, therefore, most important, and these can only be developed by experiment with adequate testing facilities. In order to ascertain the value of such insulators, no method of testing can equal a practical trial under conditions of actual service. Placing new insulators on power transmission lines in commercial operation is impracticable in most cases and should only be permitted after they have successfully withstood tests to demonstrate their

ability to stand operating conditions. These tests should duplicate as nearly as possible the electrical and mechanical strains set up in the insulators under the most severe conditions that would ever be met with on a transmission line.

There are certain facts which must be considered if correct deductions are to be made from insulator tests. For instance, we cannot test each insulator with a given number of volts continuously as it would be in service. As is well known, all insulating materials are most apt to break down on long applied electric stress. The prepared cloth wrappings used on the windings of electrical machinery will stand instantaneously two or three times the potential that they will carry continuously. Glass and porcelain are not affected by time to the same extent as organic materials, but we know that both kinds of insulators have been punctured by long continued applications of lower pressures than those which they have withstood in tests of short duration.

The shape of the potential wave also has a pronounced effect in breaking down insulation. A wave may be either flat topped or peaked, so that the maximum instantaneous potential is much less or greater than that of a sine wave of the same square root of the mean square potential. We might have for the same potential as read by the voltmeter, maximum instantaneous potentials which differ as much as two to one.

In air, the maximum point of the wave determines the distance which the current will jump. Different generators or even the same generator under different conditions of load will show widely varying arcing distances for the same potential.

Insulating materials being more affected by time than air, show in their ability to resist puncture that the average potential of the wave is more important than the maximum.

It is not safe to assume the potential either by the voltmeter or air gap as the true potential for determining the insulating value, as it is somewhere between the two. Moisture in the atmosphere also effects the arcing distance. In steam, a given potential will jump twice as far and in a fog 25 per cent. farther than under ordinary conditions. Of course, if the altitude is high and the air more rarified, the arc will also jump a greater distance.

I would like to call attention to the characteristics of the apparatus required for testing insulators.

The alternators generally used for long-distance transmission plants give very nearly a sine wave and therefore the testing generator should be one which will give a sine wave under all

conditions. It is not sufficient to do so at full potential and no load, as tests are made with all degrees of excitation and with both leading and lagging currents.

The armature reaction should be as small as possible, which means that the generator should be much larger than would ordinarily be thought necessary. It is also desirable to have a high reluctance in the magnetic circuit to secure stability when running with weak fields and permit of control with a reasonable amount of field resistance.

There should be but one transformer used to step up to the highest potential required and its reactance should be as low as possible. A number of transformers in series is particularly bad, as it gives poor regulation and leads to great uncertainty as to the actual potential to which an insulator is being subjected.

I have known testing sets with transformers in series and a generator of poor regulation to vary widely in the relation of the generator volts and the length of the spark gap due to change of wave form with different magnetic saturations of the apparatus and different numbers of insulators and consequently various capacities on the testing circuit. The only certain way to determine the real potential is to have a step-down instrument transformer on the high potential circuit.

Assuming that insulators are to be passed upon for a specific transmission plant, they should first be inspected to see that they are free from cracks, bubbles or pits that will impair their strength or in which moisture can lodge. If of porcelain, the glaze should cover all the outer surfaces. The glaze is of no insulating value in itself, but dirt sticks to unglazed surfaces.

Experience has shown that porcelain insulators which are not absolutely non-absorbent are worthless. The best porcelain shows a polished fracture like glass. If there is any doubt about the quality of the porcelain in this respect, it should be broken into small pieces, kept in a hot dry place for some time, weighed, and immersed in water for a day. When taken out of the water the weight should be the same as at first. A puncture test should be made by setting the insulator in a cup of salt water, filling the pin-hole also with water and slowly increasing the potential between the top and bottom until the desired test potential is reached or the insulator either punctures or arcs over the surface.

If an insulator is built up of several parts, each part should be able to withstand a pressure greater than it will have to sustain

when the complete insulator is tested. If it is to be tested for 100,000 volts and is made in two parts, each part might, for instance, be tested with 70,000 volts. The object of this is to have the weak parts rejected before they are assembled. A fair puncture test for an insulator is twice the potential for which it is to be employed, applied between the head and the interior for one minute. For example, the insulators for a 50,000 volt line should each stand 100,000 volts. As the potential from any wire to ground on a 5000 volt three-phase system would only be about 30,000 volts, a 100,000 volt test gives a factor of safety of nearly three and one-half to one. If one branch were grounded, as sometimes occurs in practice, the factor of safety would be but two to one. A one-minute test is not so severe as a continuous application of an equal potential, but insulators that have passed this test stand up well in service.

New types of insulators should be mounted on iron pins and tested both wet and dry, to determine the potentials which will arc over them. The dry test is of little value, as the potential at which the arc jumps from the head to the pin can be predetermined by measuring the shortest distance between them and referring to a curve of arcing distances in air. In a wet arcing test, a stream of water from a sprinkler-nozzle under a pressure of at least 50 pounds to the inch should be played on the insulator at an angle of say 30 degrees from the horizontal. This will be similar to the condition which exists in a rain and wind storm. The insulator should not arc over from the wire to the pin at less than the potential which will exist in service between any two conductors.

In no case should wooden pins be relied on for insulation, as their value is only temporary. All wooden pins in time become dirty, absorb moisture and eventually burn off unless the insulator is good enough to be used with an iron pin. If an insulator is going to fail, it is better to have it do so at the start and not interrupt the service by breaking down perhaps years afterwards.

In addition to the electrical tests, it is well (if the insulator is of a type that seems to require it), to try samples for mechanical strength. When mounted on pins the insulator should stand a side strain of at least ten times the pressure exerted by the air on the conductor with a wind velocity of, say, 100 miles an hour.

It should also be able to slip the conductor through the tie-wire should the former break.

These tests are particularly desirable with built-up insulators in order to be certain that the parts will not separate. With such insulators, it would also be well to test them in tension along the axis of the pin, as in transmission lines crossing depressions such an upward pull is not infrequently exerted on the insulator.

The above notes and suggestions are the result of the writer's tests of insulators, and observations of high potential lines. There are many members of the Institute whose experience has been wider and who have doubtless given the matter much thought.

It is the purpose of this paper only to touch briefly upon an important subject in order to open a discussion which it is hoped will bring out much valuable information.