The Dielectric Discharge Test

Introduction

The Dielectric Discharge (DD) Test is a diagnostic insulation test that allows aging and deterioration of insulation to be assessed. The result is dependent on the discharge characteristic so the internal state of the insulation is tested, largely independent of any surface contamination. The charge that is stored in the sample is measured during the discharge phase. The DD test is automatic on some MEGGER® insulation testers making it very simple to carry out.

Charging Insulation

During an insulation test the charging rate depends on the capacitance of the sample, the absorption rate, the leakage current plus the output current of the insulation tester.

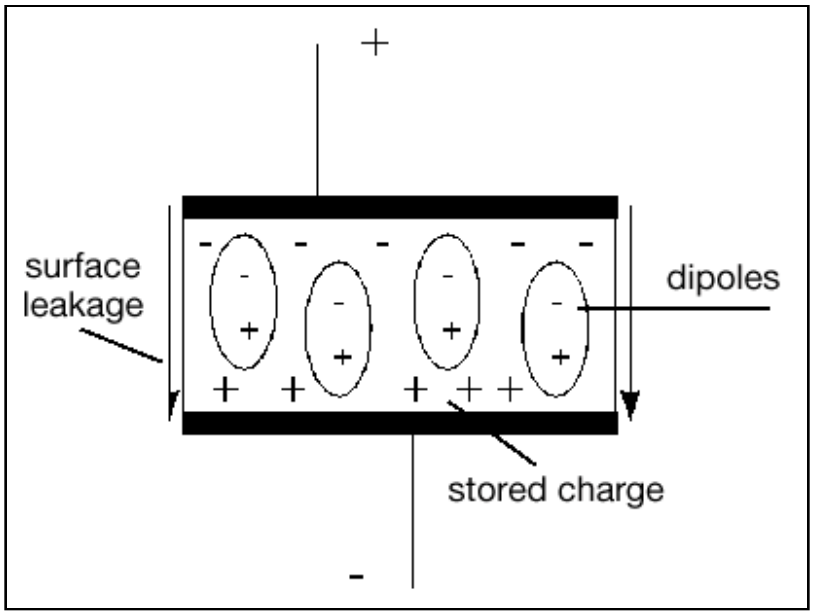

Figure 1. Insulation test currents during charging

Capacitive Charging Current

The insulation material becomes charged in the same way as a dielectric in a capacitor. This charging is dependent on the capacitance value and the resistance of the source. This effect usually decays in a few seconds.

Absorption Current

In addition to the capacitive charging, dipoles align in the electric field within the material and some charges are able to move slightly. These charging effects cause absorption current which have a long time constant. They will return to their natural, random state slowly when the test voltage has been removed (causing reabsorption current). These effects are lengthened when the insulation has been contaminated by dirt or moisture. Depending on the type of insulation this may take as long as 30 minutes.

Leakage Current

The leakage current is dominated by surface leakage but includes leakage through the insulation. This is the resistive current that would be measured when the insulation is fully charged and full absorption has taken place.

Surface leakage can be removed by use of the 'Guard' terminal.

Total Current

The total current is measured by an insulation tester to calculate the insulation resistance. To analyse the insulation, the time - resistance characteristics can be used to assess how the charging currents are varying.

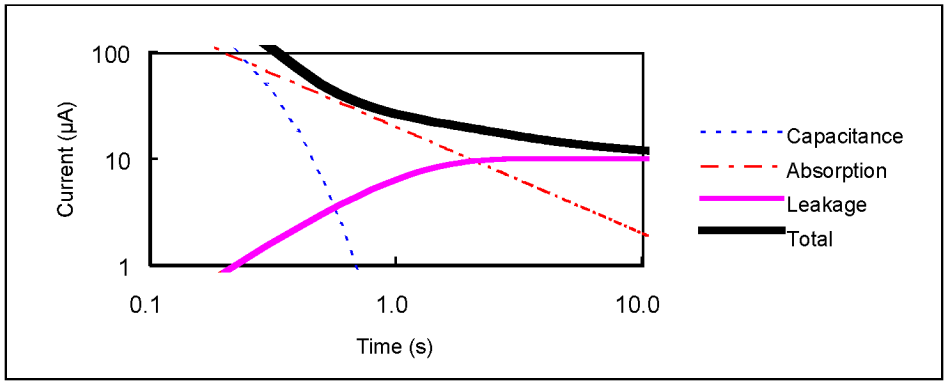

Figure 2. Typical insulation test currents

The charging characteristics can be used to assess the quality of the insulation in the polarisation index (10 minute:1 minute) or dielectric absorption (60seconds:30 seconds) tests. These ratios can be used to evaluate the level of contamination of the sample because the difference between the absorption and leakage current is measured. Excessive leakage current will swamp absorption current, leading to a flatter time-resistance curve.

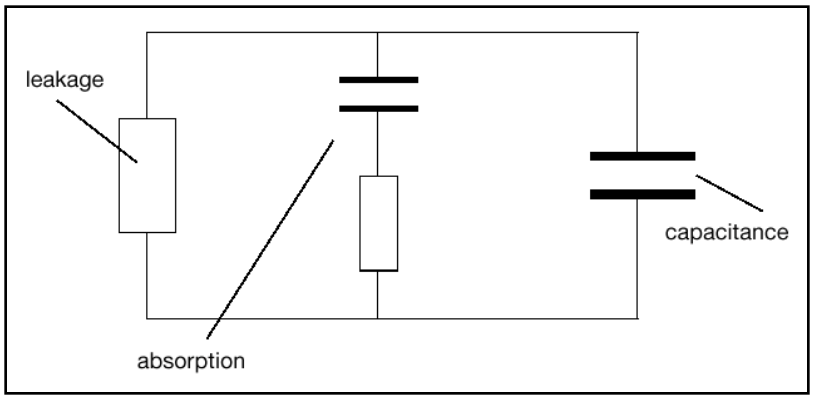

Figure 3. Equivalent Circuit of Insulation

Insulation Discharge

The charge that is stored during the insulation test is automatically discharged at the end of the test when the insulation tester's discharge resistors are switched across the terminals. The rate of discharge depends only on the discharge resistors and the amount of stored charge from the insulation. When the voltage across the insulation has

reduced to almost zero the effect of surface leakage will be very small.

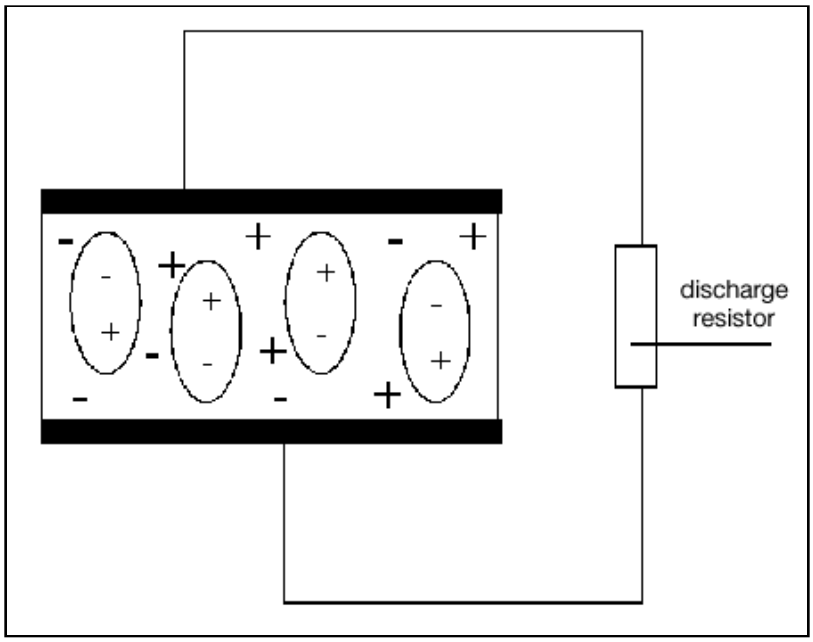

Figure 4. Insulation test currents during discharge

The discharge currents change in a similar way to the charging currents; the capacitive current decays quickly due to the time constant of the capacitance and the discharge resistors, the absorption current decays slowly as reabsorption effects take place.

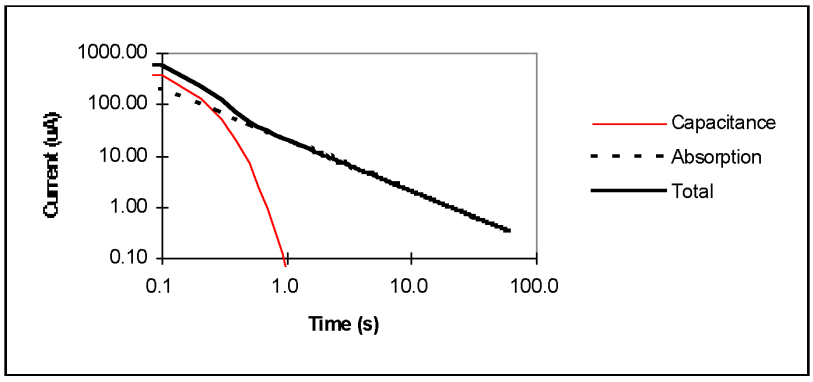

Figure 5. Typical insulation discharge currents

Reabsorption Current

The capacitive current quickly decays from a high value with a relatively short time constant (a few seconds). The absorption (or reabsorption during a discharge) current starts from a lower level but has a much longer time constant (up to several minutes). It is caused by ions and dipoles re-aligning themselves within the insulation. When an electric field is applied some ions are able to move and some dipoles align themselves within the field.

These effects reverse themselves slowly when the test voltage is removed caused by particles returning to their natural, random state. This can have the effect of a current flowing if the discharge circuit is still connected, or a voltage reappearing on the sample if it is left open circuit.

The DD test measures the discharge currents 1 minute after an insulation test has been completed. At this time the capacitive current has usually become insignificant compared with the reabsorption current. The level of reabsorption after this time shows the state of the insulation material, providing the insulation has been fully charged for full absorption to take place (typically 10 to 30 minutes). A high reabsorption current shows that the insulation has been contaminated, usually by moisture. A low current usually shows that the insulation is clean and has not absorbed much water.

Dielectric Discharge Definition

The dielectric discharge test measures the discharge current 60 seconds after the insulation test is finished. This is converted to a figure of merit which gives a figure for the quality of the insulation, independent of the test voltage. This is temperature dependent so it is important to test at a reference temperature or record the value.

The DD value is defined as (in mAV-1F-1):

$$\frac{Current\ \ flowing\ after\ 1\ minute(nA)}{Test\ Voltage(V) \leftrightarrow Capacitance(\mu F)} = \frac{I_{1\,\min}}{V \leftrightarrow C}$$

Multi-layer Insulation

Insulation in high voltage equipment often consists of layers, each having its own capacitance and associated leakage resistance. When insulation is built up in this way, the aim is to make each layer such that the voltage stress is shared equally between layers. When the insulator is discharged each layer's charge will decrease equally until there is no voltage remaining.

The DD test result can also show how similar the layers of insulation are. In the case of insulation failure in a single layer of insulation the leakage resistance will decrease but the capacitance is likely to remain the same. This type of fault is not possible to detect from a standard insulation test because the overall resistance will remain high due to the other, high resistance, layers. Similarly, other tests such as time-resistance measurements, step voltage tests or capacitance measurement will not necessarily show any particular problem. Measuring the discharge current can show when the resistance-capacitance characteristic is incorrect. This effect is smaller than the absorption effects mentioned previously.

DD Test Result Analysis

A low DD value shows that the reabsorption current is decaying quickly and the time constant of each layer of insulation is similar. A high value of DD shows that the reabsorption current exhibits long relaxation times which may point to a problem with the insulation. Typical conditions from practical research, primarily carried out on generators by a major utility, arrived at the figures of merit in the table below. This technique was developed for HV generators but may have application where insulation condition needs to be determined for other electrical equipment.