An Introduction to Insulation Resistance Testing

In a perfect world, electrical insulation would allow no current to flow through it. Unfortunately, a number of factors can over time result in the deterioration and ultimate failure of electrical insulation. Excessive heat or cold, moisture, dirt, corrosive vapors, oil, vibration, aging, and damaged wiring can all compromise an insulation system. Faulty insulation can result in equipment underperformance and downtime, and pose a serious danger to personnel.

To assess and monitor insulation integrity, several tests have been developed. These typically involve injecting a test voltage and then measuring resistance. This "stress tests" the insulation, similar to applying high water pressure to plumbing to test for leaks.

A regular program of resistance testing can detect insulation deterioration so it can be addressed before it becomes a major problem. Insulation resistance testing helps ensure personnel safety and optimal operation of equipment. It also helps evaluate the quality of repairs that may be required before equipment is put back into operation.

In this article, we discuss three commonly used methods for testing insulation resistance: the ***Spot Reading*** test, the ***Time Resistance*** test, and the ***Step Voltage*** test. These three tests are used primarily to test motor, generator, cable, and transformer insulation.

To perform these tests, you will need a megohmmeter with a timed test function. AEMC® Instruments offers a complete line of megohmmeters designed for insulation testing, ranging from 100V handheld instruments to heavy-duty models providing test voltages up to 15,000V.

And with some models, you can download and analyze the results on a computer running AEMC's DataView® software.

You will also need a thermometer or similar temperature measurement device. And if the equipment temperature is below the dew point, a humidity measuring instrument will be necessary, especially when performing a spot test.

Safety

Before performing any insulation resistance test, be sure to observe the following safety measures, as well as any additional guidelines specified in the documentation that comes with your test instrument. Insulation resistance testing involves the application of high DC voltages. Properly preparing the system under test, and the instrument used to conduct the test, is crucial to your safety and helps prevent damage to your wiring and machinery.

Take the equipment under test out of service. Shut down the apparatus, open all switches, and de-energize the unit. Disconnect from all other equipment and circuits, including neutral and protective ground connections. Be sure to follow proper lock-out/tag-out procedures during this step.

Perform a thorough inspection of the system. In general, the more equipment included in a test, the lower the resistance reading. Therefore it is critical to inspect the system and understand exactly what you're including in the test. Make note of any equipment that might be damaged by high test voltages, and either adjust the test voltage accordingly or exclude these components from the test.

Discharge capacitance before and after conducting an insulation resistance test. Note that AEMC® megohmmeters automatically discharge capacitance when not running a test.

Check current leakage at switches and other connections.

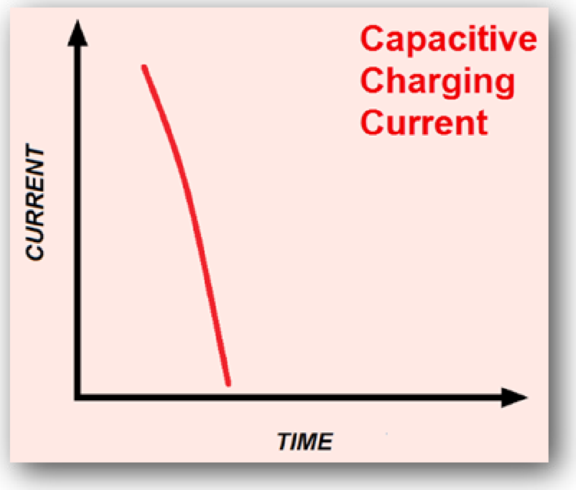
When performing the test, restrict personnel access to the test site. Also, be sure to use personal protective gear such as gloves where appropriate.

And after the test is complete, make sure the system under test is fully discharged. A minimum discharge time of four to five times the duration of the applied test voltage is recommended. Some insulation resistance test instruments feature a built-in circuit to ensure a safe discharge after the test. Instruments with this capability ensure devices are safely discharged after every test.

The Three Components of Insulation Current

To properly interpret test results, it's important to understand that the total current flowing through the insulation consists of three components: capacitance charging current, absorption current, and conduction or leakage current.

Charging Current:



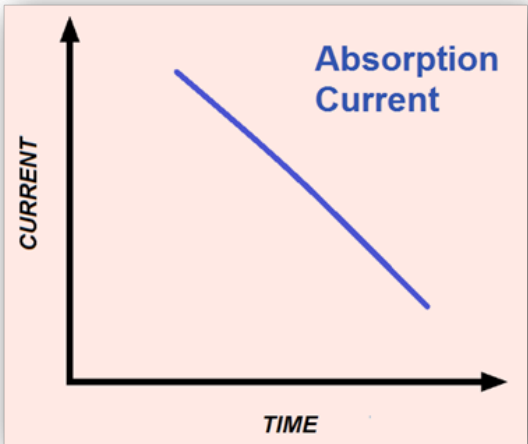
When two conductors are in close proximity separated by an insulator – for example, a length of common two-wire electrical cord -- they can act as a capacitor.

When test voltage is first applied, this capacitive charging effect results in current flowing through the conductors until the voltage across the insulation reaches the test voltage. Consequently, the initial resistance measurement will be relatively low and then quickly rise as the capacitance becomes fully charged.

This effect is usually brief; often lasting less than a second (although on very long cables or large motors this can last much longer, up to 30 minutes or more). Capacitive charging current is not an indicator of insulation quality; but it needs to be accounted for to ensure your measurements are meaningful and relevant.

Absorption Current:

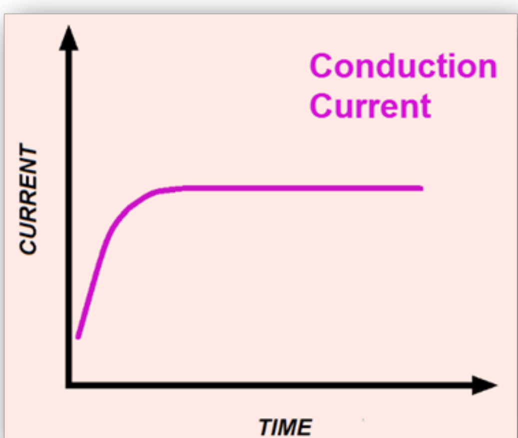
Absorption current, also called polarization absorption current, is caused by the insulating material becoming polarized by the electricity flowing through the conductor. As the polarization level increases, the absorption current decreases.



This gradual change reflects the storage of potential energy in and along the insulation. As a result, resistance is initially lower and then rises. This produces a measurement profile similar to capacitive charging current, but at a much slower rate; the effect can last from several seconds up to a minute or more.

The length of time it takes for absorption current to fall can be affected by moisture or other contaminants in the insulation material. Therefore absorption current is an important indicator of insulation integrity.

Conduction Current:

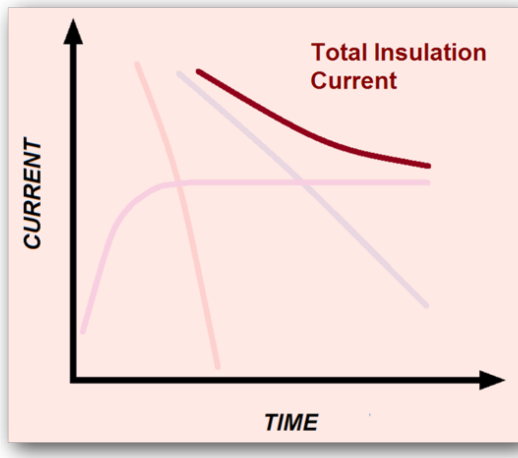


Conduction current, often called leakage current, is the steady current present both through and over the insulation.

This is a critical measurement, since an increase in conduction current over time is likely an indication of deteriorating or damaged insulation.

To summarize: for a typical test, the initial measurement primarily reflects capacitance charging current. After a period of time, absorption current is dominant. And beyond one to ten minutes, the measurement is mainly determined by conduction current, the primary value used to calculate the quality of insulation resistance.

Combining these three components produces a total insulation current profile similar to the illustration shown below:



Understanding how these individual currents contribute to the total insulator current can help you correctly interpret the results you receive when performing a test.

Environmental Factors

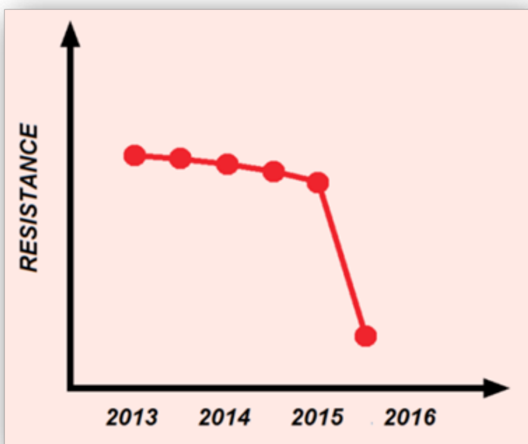
It's also important to be mindful of how environmental factors can affect resistance. For example, oil or soot on the equipment's surface can lower insulation resistance. And if the equipment's surface temperature is at or below the dew point of the ambient air, a film of moisture forms. This can significantly lower the equipment's resistance value.

Temperature is also a critical consideration. Insulation resistance can vary with temperature, with different materials exhibiting different rates of change. Ideally, all resistance testing should be done at the same temperature. If this is not possible, temperature should be carefully recorded so correction factors can be applied to the resistance measurements.

Spot Reading Test

The first type of insulation resistance test we'll examine is the Spot Reading test. This is relatively straightforward: simply connect the megohmmeter leads across the insulation to be tested, apply test voltage for a fixed period of time (typically one to ten minutes), then take a resistance reading. Spot testing is suitable for a system with small or negligible capacitance effect, for example a short wiring run.

A single Spot Reading test is of limited value; but the results become meaningful when a series of tests, all featuring the same test voltage and duration, are performed over time and the results compared. This comparison can help predict a potential insulation failure in time to take corrective action.



For example, suppose you perform a spot test every six months. By plotting the results on a graph, you observe a slow and gradual downward trend, as would be expected by the normal aging of the insulation. However, your latest measurement reveals a sudden drop in resistance. This is likely indication that the insulation has begun to deteriorate at an accelerated rate. To address this, you can schedule downtime for the system and take appropriate measures such as cleaning, upgrading, or replacing the insulation.

To ensure your results are valid, spot testing should ideally only be performed on systems with temperatures exceeding the dew point. If tests are performed at different temperatures, carefully record the temperature of each test and apply the appropriate correction to determine what the resistance would be if the test were performed at 68° F (20° C).

Time Resistance Test

Another insulation resistance measurement method is the Time Resistance test, also referred to as the dielectric absorption test. It involves conducting a 10 minute test. For the first minute, during which absorption current will have the highest effect on resistance, measurements are taken every 10 seconds. After the first minute, measurements are taken once per minute.

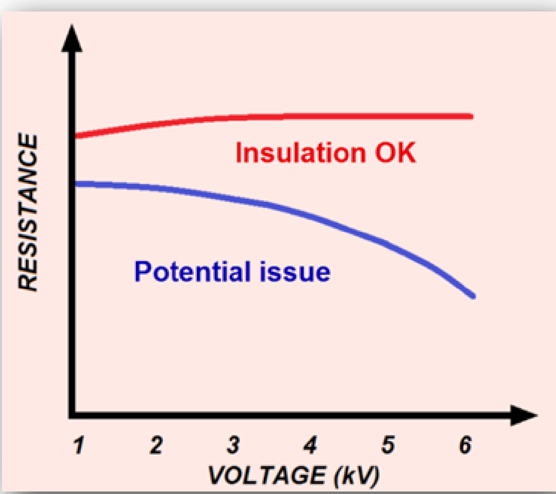
When you plot the results, you should see a curve that rises relatively rapidly at first, and then continues to gradually rise throughout the testing period. If instead the curve is relatively flat or begins to turn down as the test progresses, moisture, dirt, or other factors may be compromising your insulation.

Time Resistance tests on large rotating electrical machinery, especially systems with high operating voltage, require high insulation resistance ranges and a very constant test voltage. Since this test provides meaningful results within a single 10-minute duration, it is relatively independent of temperature. It is also independent of the size of the system under test.

The Time Resistance test is sometimes associated with two values, the ***Polarization Index***, or PI, and the ***Dielectric Absorption Ratio***, or DAR. The Polarization Index is derived by dividing the 10 minute resistance measurement by the 1 minute measurement. The Dielectric Absorption Ratio is calculated by dividing the 1 minute measurement by the 30 second measurement. Although DAR is no longer commonly used with newer insulation systems; it still may have applicability when testing older insulation materials.

Step Voltage Test

A third method is the Step Voltage test. This involves testing at least two or more test voltages and comparing the results. The test begins at an initial test voltage. At a specified interval, typically one minute, a measurement is recorded, after which the test voltage is increased. This increase is usually to five times the initial voltage. This process may be repeated through several steps, with measurements taken after one minute and the test voltage increased at a five to one ratio over the previous voltage. A common practice is to test at five voltage steps.



The Step Voltage test is designed to create electrical stresses on internal insulation cracks, identifying potential problems that may not be revealed by testing at lower voltages. Insulation that is thoroughly dry, clean, and in good physical condition should provide roughly the same resistance measurements across the voltage range. If instead you observe a significant decrease in resistance at higher voltage, your insulation may be contaminated or deteriorating.

Step Voltage testing is also often used as a way to dry wet cables or equipment. Gradual voltage steps, applied for increasingly longer durations, can facilitate drying through heating.

This concludes our quick introduction to insulation resistance testing. As noted earlier, AEMC® offers a complete line of megohmmeters designed for quick and accurate testing of electrical insulation in a variety of devices, environments, and applications. Consult the AEMC® web site for to learn more about these instruments. And be sure to check our **YouTube channel** for further information about insulation testing and other topics in electronics.