Question: What is the difference between Meg-Ohms, Gig-Ohms and Tera-Ohms? We have several different Insulation Resistance testers and they have different specifications. Is Tera-Ohm trending better than Gig-Ohm or Meg-Ohm trending?

Answer: First, remember we are talking about electric motors here, in the real world. Not laboratory measurements.

Mega-Ohms, or Meg-Ohms: The prefix Mega is the indicator that the number described is raised to the 6th power. So for example, 1 Meg-Ohm is exactly 1 million ohms. A value of 500 Meg-Ohms is exactly 500 million Ohms. If a 480VAC motor, tested at 500VDC with an insulation resistance meter, indicates a value of 500 Meg-Ohms, it means .000001 Amps is flowing through the electric insulation. .000001 Amps is 1 millionth of an Amp. For those that care about power dissipation, this is equal to .0005 Watts, or about 1/7000th the power required illuminate a single 3 ½ Watt Christmas tree bulb.

It is common to see functional, high quality, electric motors with insulation resistance values in the Meg-Ohm range. Most guidelines suggest 1 Meg-Ohm per KV operating voltage plus 1 as a MINIMUM acceptable Meg-Ohm value for electric machines. The 480VAC example cited above would have a minimum acceptable value of 1.48 Meg-Ohms for continued service.

Giga-Ohms or Gig-Ohms: The prefix Giga is the indicator the number described is raised to the 9th power. It is indicative of a much larger number than Mega-Ohms. A value of 1 Gig-Ohms is exactly 1 billion Ohms. 1 Gig-Ohm is equal to 1000 Meg-Ohms. If we use the example above, of a 480VAC motor, tested at 500VDC indicates a value of 500 Gig-Ohm. That means .000000001 Amps is flowing through the insulation of the motor. This is 1 billionth of an Amp. If we cite the above example about Cristmas tree bulbs, it means a grand total of 1/7000000th the power required to illuminate a single 3 ½ Watt bulb.

It is common to see functional, high quality, electric motors with insulation resistance values in the Gig-Ohm range. IEEE standard 43 2001 states that values of insulation resistance above 5 Gig-Ohms may not be useful for machine condition trending purposes. Remember, 5 Gig-Ohms is equal to 5000 Meg-Ohms.

Tera-Ohms or Ter-Ohms: The prefix Tera is the indicator of a number raised to the 12th power. Again, it indicates a much larger number than either Meg-Ohms or Gig-Ohms. A value of 1 Ter-Ohm is exactly 1 trillion Ohms. 1 Ter-Ohm is equal to 1000 Gig-Ohms and 1000000 Meg-Ohms. If we use the example cited above about the Christmas tree bulb, we find the 480VAC motor at 500VDC with a 500 Tera-Ohm Insulation resistance will be allowing .000000000001 Amps of current to flow. This means that a grand total of 1/700000000000000th of the power required for a single 3 ½ Watt Christmas tree bulb will be flowing through that insulation.

Electric motors with insulation resistance values in the Ter-Ohm range are seen, but not nearly as often as lower values.

Why?

By the very nature of their application, electric motors are found in uncontrolled industrial environments. They are almost never; clean, dry, or un-contaminated with surface deposits. The extreme low level measurements obtained with Ter-Ohm meters are dramatically influenced by the environment. For example: The air we breathe becomes part of the measurement circuit. It's influenced by: humidity, particulates/ aerosols and altitude. At 10000 feet elevation, air itself is 20% less resistive per unit distance. Changes in humidity have dramatic effects on surface leakage currents, due to condensation of water molecules on the surface of the insulation. Large amounts of particulates or aerosols will reduce the unit resistance. They allow tracking effects to take place, where the particles become polarized circuit elements, and reduce the measured resistance.

In other words: Tera-Ohm measurements are more likely than Giga or Mega-Ohm measurements to be influenced by environmental factors. Thus, they are more likely to give potentially misleading results.

Extreme care must be taken when evaluating Tera-Ohm readings for machine condition analysis.

What are typical leakage currents in large electric motors during insulation resistance testing? What kind of equipment is necessary to adequately determine a motor's insulation resistance?

Consider a 4160V motor tested at 5000V, an acceptable test voltage for testing 4160V motors. The table below shows a range leakage currents and insulation resistance's that would be measured during a 5000V IR test.

V=5kV

Leakage Current	Insulation Resistance
100 µA	50 Meg-ohms
10 µA	500 Meg-ohms
1 µA	5,000 Meg-ohms
0.1 µA	50,000 Meg-ohms (50 Gig-ohms)
0.01 µA	500,000 Meg-ohms (500 Gig-ohms)
0.001 µA	5,000,000 Meg-ohms (5,000 Gig-ohms)

IEEE 43 recommends 1Meg + 1Meg/kV or 1Meg + 4Meg or 5Meg for the minimum insulation resistance for a 4160V machine. The leakage current for 5 Meg ohms at 5000V is 1000uA. If the insulation resistance is greater, then IEEE 43 says the motor's insulation is in acceptable condition. Obviously, such a low IR is uncommon. More likely, the insulation resistance will be in the 100's of Meg ohms.

Now consider performing a polarization index test (PI test) on the motor. IEEE 43 gives a lower limit on the leakage current necessary to make good PI measurements. IEEE 43 says that if the insulation resistance is greater than 5000 Meg ohms at one minute, the PI value may not be meaningful. From the table above, 5000 Meg ohms corresponds to a leakage current of 1uA. Being able to measure significantly lower leakage currents, say 0.1uA, will not contribute any extra information regarding the condition of a motor's ground wall insulation.

So, in the case of the 4160V motor, being able to measure leakage currents on the order of 1uA is all that is needed to evaluate the ground wall insulation.

Now consider a 480V motor tested at 500V, an acceptable insulation resistance test voltage per IEEE 43. The table below shows the IR value that would be measured given a range of leakage currents:

V=500V

Leakage Current	Insulation Resistance
100 μA	5 Meg-ohms
10 μA	50 Meg-ohms
10 μA	500 Meg-ohms
1 μA	5,000 Meg-ohms
0.1 μA	50,000 Meg-ohms (50 Gig-ohms)
0.01 μA	500,000 Meg-ohms (500 Gig-ohms)

IEEE 43 suggests that an IR value greater 1.4 Meg ohms indicates the ground wall insulation in a motor is in good condition. At 500V, 1.4 Meg ohms corresponds to a leakage current of 400uA. Per IEEE 43-2000, being able to read lower currents than 400uA is nice, but not necessary to determine the condition of the ground wall insulation based on insulation resistance. Of course, motors will have a much higher insulation resistance than 1.4Meg ohms.

Now consider the PI test for this 480V motor made at a test voltage of 500V. A lower limit to the current measurement can be determined based on the 5000 Meg ohms at 1-minute rule in IEEE 43. At 500V, 5000 Meg ohms corresponds to a leakage current of 0.1uA. Being able to measure significantly lower than 0.1uA, say half of 0.1uA, will not add any more useful information regarding the polarizability of an electric motor.

To Summarize:

Based on the above information, the two questions regarding typical leakage currents and the type of instrument required to make ground wall insulation tests can be answered. First, the range of leakage currents required to determine the health of an electric motor is between ~0.1uA and 1000uA. Second, the instruments required to make such measurements must be able to accurately measure in this range. Being able to measure lower leakage currents doesn't buy much when diagnosing ground wall insulation in motor windings. Being able to measure lower currents just costs more in instrumentation.

References:

IEEE 43-2000, Sections 5.3, table 1, 12.2 table 2, 12.3 table 3
Keithley Low Level Measurements 5th Edition