# Case Study: Medium Voltage Motor Testing Results

**Keywords:** Electric Motor, Induction Motor, Meg ohm meter. Insulation Resistance, Surge Test, Line to Line. Pass/Fail, Predictive Maintenance.

**Abstract:**

In this case study, the results of a periodic, planned, predictive maintenance test sequence on a relatively large electric motor are analyzed. The steps and concepts of the data analysis are discussed. Electrical insulation construction characteristics of a large electric motor are also briefly covered. How they may affect test results is also touched upon.

**1. Introduction:**

An important large electric induction motor driving a sump pump was part of a periodic, predictive maintenance testing program. This was at an industrial facility. The electric motor characteristics were as follows: Westinghouse, 2300 Volts, 100 HP, 25 Amps, 3 Phase, 705 RPM, Enclosure: ODP. Vertical Motor. (Enclosure type similar to Fig 1)

Figure 1

The plant operator had called for immediate testing because it had been giving problems, tripping offline. This motor is outside open drip proof vertical and it blew 2 of the 3 fuses going to the motor twice. Time for testing and troubleshooting!

**2. The testing sequence:**

The test sequence selected for this particular machine was as follows:

A) Kelvin Resistance Bridge, using the “4 wire” technique for enhanced accuracy. Temperature correction was also used to cancel effects of winding temperature deviation.
B) Insulation Resistance, using an automated meg-ohm meter. Target Voltage 500V. Pass/Fail results are attained with this particular tester type.
C) Step Voltage test, using an automated step voltage tester. Target voltage for final step: 5,600 Volts
D) Surge test using an automated surge/surge comparison tester. Target voltage for final step: 5,600 Volts

The test sequence was performed from the motor control center, through a short (less than 50 feet) length of feeder cables, from the control shack. The out door temperature was noted as 10 degrees C (50°F)

**3. The test results:**

**Winding Resistance:**
The results of the DC resistance tester were quite acceptable, with less than 0.25% unbalance indicated. The readings were:

A-B: 1.83 ohms
B-C: 1.84 ohms
C-A: 1.84 ohms
Maximum Deviation: 0.247%
PASS

The test sequence was deemed acceptable, meaning it is unlikely a hard turn to turn short circuit existed in the phase windings. The next step was the Meg Ohm test.

**Meg Ohm:**

The test was performed. The test equipment operator noted that the test voltage rose to about 400V, when the leakage current began to climb rapidly. The over-current protection for the tester tripped, and the test sequence was interrupted. The readings were:

Volts: 370V
Leakage Current: 818.50 µAmperes
Indicated Insulation Resistance: ~0 Meg Ohms.
FAIL

The motor test engineer went ahead and verified these results with a Fluke® Model 287 Multimeter. 139.9 K ohms was indicated with the multi-meter. This was confirmation of a fault condition, likely in the insulation system to earth ground.

The electric motor plant operator was notified of these results. Discussion occurred about concluding the test sequence at this time, or taking some further trouble shooting steps. The plant operator decided to authorize further testing. Therefore, a follow up test sequence with the DC step voltage test was applied.

**Step Voltage:**

The DC step voltage test is performed as a series of voltage levels. Each step is applied a higher voltage level, and the resulting leakage current is plotted. The test sequence was applied and the test equipment operator noted that the test voltage rose to about 400V, when the leakage current began to climb rapidly. The over-current protection for the tester tripped, and the test sequence was interrupted. The readings were:

Volts: 370V
Leakage Current: 855.0 µAmperes
Indicated Insulation Resistance: ~0 Meg Ohms.
FAIL

These were very nearly identical results as those obtained in the Meg Ohm test sequence.

The electric motor plant operator was notified of these results. Discussion occurred about concluding the test sequence at this time, or taking some further trouble shooting steps. The plant operator decided to authorize further testing.

**Surge Test:**

The surge test was applied as a defined series of instantaneous pulses of electrical energy. The fast pulses of energy allow the development of a momentary voltage across the turns of the electric coils.

As part of the troubleshooting sequence authorized, the plant operator had determined that the surge test would be applied as well.

Here is where this story goes from mildly interesting, to a real eye opener. This particular motor was surge tested with a very advanced, computer controlled surge tester. The surge test sequence was applied according to NEMA, EASA protocols. The surge test voltage selected was 2e +1kV. This calculates out to 5,600V. The test was applied for informational reasons, to determine if the insulation system in the phase-phase areas was weak or compromised. (This decision was made, based upon the facts that 2 of the fuses had repeatedly blown)

Perhaps unexpectedly, the surge test passed with flying colors. Here are the results:

| | | |
|---|---|---|
| | Surge Status | PASS |
| | Peak Volt(V) L1 | 5600 |
| | Peak Volt(V) L2 | 5600 |
| | Peak Volt(V) L3 | 5600 |
| | | Max P-P |
| EAR% | 4.2%,4.3%,3.9% | |

As seen above, the surge curves are very clearly balanced, with little to no observable separation between the phase response curves.

How could this have happened? Had the surge tester failed to operate properly? What is going on?

How could the insulation resistance to ground be less than 140 kilo ohms (140,000 ohms) and result in over-current protection trips being enabled, yet cleanly pass a high voltage surge test?

**Motor discussion:**

Part of the answer to this question requires an understanding of the internal construction of an induction motor, as well as the nature of the feeder cables that supply it.
Think about this a bit. The motor is driving a sump pump, and is in an open drip proof NEMA enclosure. Note the outdoor temperature was 10°C. These two items raise the possibility of water or moisture contamination. If water has penetrated the motor enclosure, it may be present in the windings, or on the surface of the electric insulation system. Possibly it is a layer of droplets, forming a layer of dew. Each of the electric coils could be coated. A large electric motor has many coils. There could be 60 or more slots in the stator. This would result in many parallel path’s for leakage current. Remember your calculation from Electric circuits 101, for resistive circuits in parallel…

If each of the end windings is contaminated with water or surface contaminates, there is a possible leakage path from each of the coils to core. In the above example, we discussed 60 coil slots in the stator. If each coil has contaminates, there are not only 60 parallel path’s for conduction – but 120! (Remember, the coils exit the core steel on the other end and there are 60 more there as well)

While there will probably not be a perfect classroom type parallel divider circuit, the point to be made is that each coil slot may “see” 1 or more Meg ohms to ground. But, when 120 parallel path’s to ground can exist, each with varying levels of leakage, the overall insulation resistance seen at the motor terminals is quite low indeed. In this case study, 5 or meg-ohms could have been present at each coil to earth.

IR *total* = The sum of all parallel coils IR coil to ground

This relatively high Meg ohm per coil is why the surge test can still pass.

This is because of the very nature of: the inductance of the electric coil, the iron/steel the motor core is built with and the very fast rise time of the surge impulse. Most surge generators in the market place that are manufactured by the leading vendors provide IEEE 522 compliant voltage rise time’s

*(Note that some vendor’s machines do not!!! Some vendor’s may not publish their specifications making direct measurement by special means the only way to verify performance.)*

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