

MOTOR & GENERATOR TESTING

High Voltage AC Withstand & Diagnostic Methods Using Very Low Frequency AC Technology – VLF



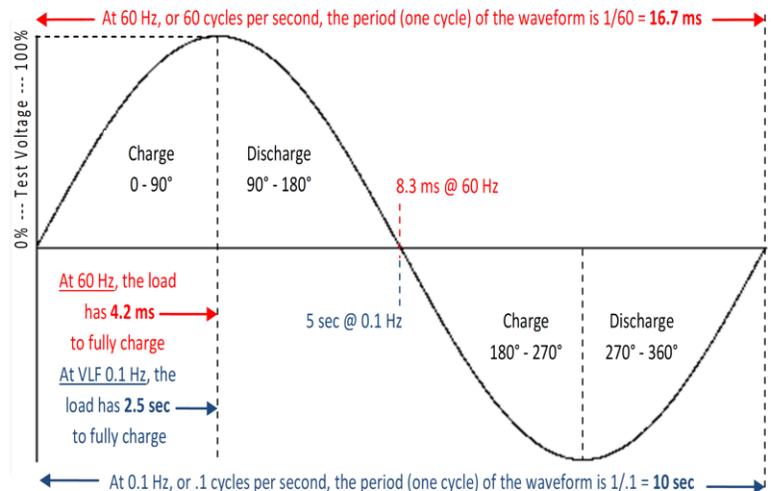
High voltage AC testing is a critical component in the testing of motor and generator coils after manufacture, rewind/repair, and/or for routine maintenance. These tests include a simple AC withstand test and diagnostic testing like Tan Delta/Power Factor measurement and Partial Discharge analysis. However, in many cases these tests are not performed, even the basic AC hipot test, because the power required from the test set to charge the capacitance of a large coil can be very high, making the purchase and use of AC Dielectric test equipment prohibitive. This problem is solved using VLF technology, the well-recognized alternative to using large, heavy, costly, and high in power draw 50/60 Hz power frequency or series resonant test sets to AC test larger coils. You can now easily and economically perform the AC testing you should as part of your routine certification, post repair verification, and/or maintenance testing program. AC testing should be performed, not DC, or worse, no HV testing at all. A 5 kVdc insulation resistance test is no substitute for a proper AC overvoltage withstand test.

VLF Technology can be used for AC Withstand and AC Diagnostic testing. VLF use for motors and generators was first defined by the IEEE Standard 433-1974, upgraded in 2009. Thousands have been shipped over the last 15 years for cable testing, some for motors. The use of VLF for coil testing is accepted and growing. With the savings in money and ease in use, why not VLF it!

VLF is easy to use, economical to purchase, light and portable, & with models from 20 kVac to 200 kVac.

What is VLF?

VLF stands for Very Low Frequency. A VLF test set is an instrument that produces an AC high voltage output but at a frequency of 0.1 Hz or lower. It is simply an AC hipot but with a frequency output much lower than the typical 50/60 Hz. Charging currents are reduced by 600x compared to 60 Hz testing. VLF technology was developed to overcome the difficulties in high voltage AC field testing highly capacitive loads that at 60 Hz require high charging currents and power to be delivered from very large, heavy, expensive, and power consuming AC test sets. With VLF technology, there is no reason to avoid testing with AC voltage.



Why use VLF?

Using VLF, it is easy and economical to perform AC high voltage testing. Applying basic physics, the lower the frequency of a voltage applied to a capacitance, like a motor winding or shielded HV cable, the lower the mA's of current, hence power, is required to charge a load to the desired test voltage. At 60 Hz, the time from 0 to peak voltage is 4.2 ms. At 0.1 Hz the time to max voltage is 2.5 seconds. With 600 times longer to charge the load at 0.1 Hz, 600 times less current is needed. Put another way, the lower the frequency, the higher the equivalent resistance of a capacitive load, $X_c = 1/2\pi fC$, drawing less current and power when a voltage is applied. VLF: Simple physics, simple to operate equipment, simple to follow test standards.

What's it All Mean?

It means that AC Withstand, or proof/hipot, and diagnostic testing requiring a high voltage AC source, are now field practical and should be performed where necessary. DC high voltage testing is not a substitute for AC in most cases and should be avoided. We now have the means to hipot high capacitance coils or long HV cables in the field with relatively portable and affordable AC test equipment. A 100 lb. VLF hipot can do the job of a multi-ton Series Resonant or 60 Hz output power supply.

AC Withstand Test @ 50/60 Hz: Electrical apparatus, like switchgear, transformers, bushings, breakers, cables, etc. must be electrically tested at a voltage higher than their normal operating level, usually at least twice normal, to prove the insulation is not faulty and no failures will occur during use. This test is known as a hipot, proof, withstand, stress, go/no-go, pressure, or over voltage test. The object either passes the test by holding the test voltage or fails by flashing over or through its insulation. It's easy, quick, conclusive, and supported by IEEE standards and used everywhere. The use of DC voltage is not recommended.

The test voltages for motor and/or generator windings are usually the following, where **E = operating line-line voltage:**
When 50/60 Hz testing, the AC rms test voltage = 2E + 1000, or $2U_o + 1$ kV, or twice the rated voltage plus 1000 volts

4,160 V motor = $2 \times 4160 \text{ V} + 1000 \text{ V} = 9,320 \text{ V rms}$. **6.9 kV motor** = $2 \times 6.9 \text{ kV} + 1 \text{ kV} = 14.8 \text{ kVac rms}$

13.8 kV motor = $2 \times 13.8 \text{ kV} + 1 \text{ kV} = 28.6 \text{ kV ac rms}$. **The test duration is typically for 60 seconds.**

The above numbers are for testing newly wound coils. Factory testing is often performed at levels even higher than shown. For "Acceptance" testing reinstalled coils, the test voltage is usually lower and for "Maintenance" testing aged coils, lower yet.

Factory Test: $\geq 2E + 1000$ **Acceptance Test:** $(2E + 1000) \times .8$ **Maintenance Test:** $\sim 1.5E$

AC Withstand Test @ 0.1 Hz: When VLF testing using 0.1 Hz instead of 50 or 60 Hz, the test voltage levels change. Research and subsequent field data conclude that a slightly elevated VLF voltage is necessary to make the different frequencies equivalent in the voltage stress applied to initiate partial discharge. Per the IEEE 433 standard, **an equivalent 0.1 Hz VLF test is 1.63x the 50/60 Hz rms test voltage.** The 1.63 multiplier however yields **peak VLF voltage**, not rms, like the 50/60 Hz voltage number. (VLF voltages are usually measured in terms of peak, not rms, as it is the peak voltage that initiates PD.) Here is a look at the test levels and multipliers. **E equals the Line-Line rms voltage** of the system: 4.16 kV, 6.9 kV, 13.8 kV, etc.

----- **Test Voltage Summary 50/60 Hz vs. 0.1 Hz** -----

Test at 50/60 Hz: $2E + 1000 = \text{rms test voltage}$ (Standards use rms for AC values, except peak is used for VLF values)
Test using VLF at 0.1 Hz: $(2E + 1000) \times 1.414$ (converts to peak) $\times 1.15$ (extra 15% V for 0.1 Hz) = **VLF peak test voltage.**
 To convert a 50/60 Hz rms test voltage to a VLF peak test voltage: $\text{rms test voltage} \times 1.414 \times 1.15 = \text{VLF peak test voltage}$
 A **13.8 kV motor** requires a test voltage of **28.6 kVac rms @ 60Hz** or **46.6 kVac peak @ 0.1 Hz** ($28.6 \text{ kV} \times 1.63 = 46.6 \text{ kV}$)

 $(13.8 \times 2 + 1000)$
 $(28.6 \times 1.414 \times 1.15)$

Tan Delta/Power Factor Testing: This is a "Diagnostic Test", not a Pass/Fail or Go/No-Go test like a Withstand test where the load either holds the test voltage or fails. This test measures the level of insulation degradation, allowing the user to make educated decisions as to maintenance or replacement priorities. The test helps to learn something of value about the insulation while minimizing the potential for failure during the test. Measurements are made quickly and the overvoltage is usually kept to less than 2 times normal. If the insulation between two conductors is perfect, a TD or PF test will show a purely capacitive element with a 90° phase shift between the applied voltage and the capacitive current. If the insulation is measurably deteriorated, the coil-core or the turn-turn insulation is no longer a pure capacitance. A resistive element is introduced. The TD or PF measurement shows the level of this change. These changes help us to decide on the integrity of the insulation. The absolute test numbers, trends over time, and comparisons to similar coils are made, **helping to prioritize maintenance or replacement work** and to determine what other tests may be useful to save a motor from in-service failure.

Partial Discharge Measurement and Analysis: Another Diagnostic test, but unlike the Power Factor or Tan Delta test that indicates the overall degradation of a coil's insulation, a Partial Discharge, or PD, test attempts to **expose the locations of electrical disturbances and their severity.** This test applies a controlled AC overvoltage to the coil while monitoring for any electrical discharges. As we increase the test voltage up to possibly $2U_o$, we measure at what voltage these discharges occur (the PD Inception Voltage), where they extinguish as we lower the voltage (the PD Extinction Voltage), and their severity. **Where are the problems and how bad are they?** We can then make an educated decision as to our repair action.

*** Contact High Voltage, Inc. for more on VLF motor testing and other HV testing applications. **
 HVI also produces a full line of high power 50/60 Hz. AC test sets. Ask for our HPA Series brochure.*