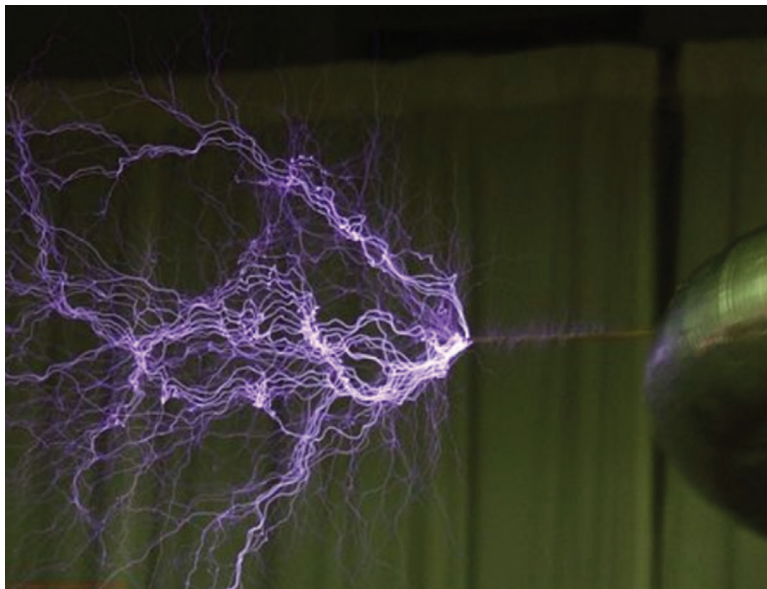

How to Work Safely with High-Voltage Test & Measurement Equipment

Vitrek's advanced 4700 High Voltage Meter and SmartProbes offer alternative to legacy approach to calibrating high-voltage systems.



INTRODUCTION

When working with high-voltage test and measurement equipment, electrical and test engineers strive to achieve the most precise readings possible while also maintaining a safe work area. Typically, they employ external probes such as high-voltage dividers, but these instruments come with drawbacks and are prone to errors.

This whitepaper describes an alternative approach to calibrating high-voltage systems. The advanced solution comprises Vitrek's 4700 High Voltage Meter for direct measurements up to 10 kV and SmartProbes, which extend measurements up to 150 kV. The paper also provides meter and probe safety considerations, as well as general guidance for safely operating high-voltage equipment.

HIGH-VOLTAGE APPLICATIONS

High-voltage applications are everywhere. They span numerous industries, including high-tech, medical, automotive, industrial manufacturing, aerospace, research laboratories, government security, and many more. The high-voltage systems used in these applications include:

- Switchgear
- Insulators
- Instrument transformers
- Reactive power equipment
- Power transformers
- Relay panels
- Switches
- Control equipment

HIGH-VOLTAGE TEST & MEASUREMENT INSTRUMENTS

Measuring high-voltage systems during design, manufacturing or in calibration labs is essential for meeting various global reliability and safety standards as well as manufacturers' warranty requirements. The high-voltage test and measurement instruments used for this calibration include:

- Meters
- Hipot testers
- Signal sources
- RF power amplifiers
- Power supplies
- Voltage dividers
- Oscilloscopes

LEGACY APPROACH: VOLTAGE DIVIDER

A commonly-used external probe used to measure higher voltages is a voltage divider. It is composed of a series of identical precision resistors. For example, a 100:1 voltage divider (Figure 1) would allow an instrument with a 1 kV max input to measure an applied voltage of up to 100 kV.

The voltage divider's large number of carefully matched resistors will (theoretically) eliminate errors from self-heating or other factors that affect the resistor string in a uniform fashion. Even so, there remain a number of contributing factors to error and uncertainty:

- Resistance variation from one resistor to another
- Variations (although minor) in temperature coefficient
- Electromagnetic effects
- Capacitance effects
- Variation in meter input impedance, which necessitates that it must be calibrated with the meter.



Figure 1. Example of a typical voltage divider network.

Voltage Divider: Accuracy Concerns

The voltage divider network is susceptible to a number of error-producing effects, among them, self-heating, capacitance effects on AC measurements and electromagnetic effects.

Calibration of a voltage divider with a meter also needs to identify sources of uncertainty. As stated in one manufacturer's materials:

For highest accuracy in high impedance, low input capacitance types, consideration must be given to induced voltage pick-up in leads, contact potential, corona, effective capacitance, and voltage gradient and capacitance shift related to proximity to high voltage sources, ground planes, walls, enclosures, and loads.

Preferably the divider should be calibrated with the specific instrument being used and specific proximities if extreme accuracy is required. Greatest accuracy, particularly AC accuracy, is attained with proper ground plane and if maximum clearance to conductive materials, which can cause capacitance variation and corona. If available, user's proximity dimensions will be simulated when calibrating.

ALTERNATIVE SOLUTION: VITREK 4700 HIGH VOLTAGE METER & SMARTPROBES

Vitrek's 4700 High Voltage Meter (Figure 2) offers performance that rivals traditional high-voltage reference dividers – but unlike using a divider, the 4700 provides instant, direct, high-voltage measurements in a highly portable, compact and rugged bench top enclosure. Vitrek's 4700 precisely measures voltages directly up to 10 kV (10m kV DC or rms AC directly) without using external probes.

The 4700 is capable of meeting High-Voltage Specifications:

- Base accuracy: 0.03% DC, 0.1% true RMS plus limitations and adders (no range adder needed): Maximum voltage: 10 kVDC, 10 kVACRMS
- Impedance: 110 Mohm
- Ranging: None
- Noise Floor: 30 mV
- Frequency response: 0.01 Hz to 600 Hz
- Offsets: Up to 800 V
- Differential measurements if two external probes are used

To extend high-voltage measurements beyond 10 kV to 35 kV, 70 kV, 100 kV and up to 150 kV, Vitrek SmartProbes (Figure 3) can be added to the 4700 High Voltage Meter.

Unlike voltage dividers that must be calibrated with the meter, each SmartProbe stores its own calibration data, which is downloaded when plugged into the 4700 High Voltage Meter. This results in highly accurate, calibrated readings and allows any SmartProbe to be used with any 4700.

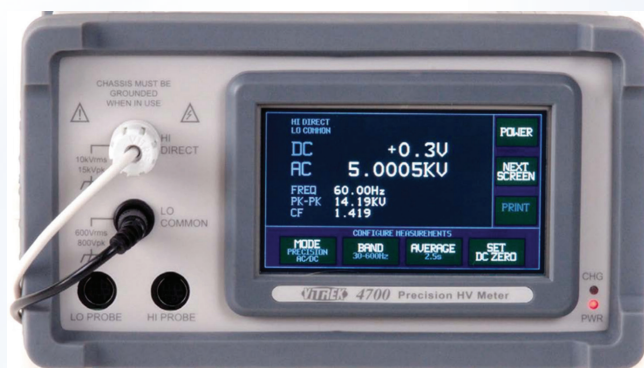


Figure 2. Vitrek 4700 High Voltage Meter



Figure 3. Three Vitrek SmartProbes™ shown with detachable probe tip

HIGH-VOLTAGE INSTRUMENTS - ACCURACY & SAFETY CONSIDERATIONS

High-voltage measurements are susceptible to errors due to environmental factors, such as nearby capacitive objects, water, dust and chemicals. At elevated voltages, electromagnetic effects must be considered. Simply walking past the measurement setup can cause errors. Other sources of error are:

- Drift over time: One year cal cycle
- Capacitance: Nearby objects, moving objects
- Humidity
- Drift with temperature: +- 5C from temperature at cal
- Corona effect: Purple glow that leaks energy

HIGH-VOLTAGE INSTRUMENTS - ACCURACY & SAFETY CONSIDERATIONS

4700 High-Voltage Meter Considerations

Instructions in the operator's manual for the Vitrek 4700 Precision High Voltage Meter provides insights into the importance of working in a controlled environment:

- The 4700 should not be used in an environment where conductive pollution can occur (e.g., in an outdoor environment).
- If fluids or other conductive materials are allowed to enter the unit enclosure, even if not powered, then the unit should be immediately taken out of operation and serviced as safety may have been compromised.
- If the unit is transported between different environments and condensation is suspected, the unit should remain unpowered for sufficient time for condensation to have dissipated.
- When ac voltages are present, even if there is sufficient insulation on the connections, there may be significant capacitive coupling which can cause an unsafe current to flow into nearby objects and also corona may occur even outside of the insulation. These effects are made worse by sharp corners. In severe cases corona can cause interference with the measurements of the 4700 and will reduce the capabilities of the wiring insulation over time, eventually resulting in insulation failure.

SmartProbe Considerations

The high voltage measurement range of the 4700 High Voltage Meter can be expanded by using one or two (differential) SmartProbes. Users should simply plug in one or more (35 kV, 70 kV, 100 kV, 150 kV) SmartProbe as needed.

Each SmartProbe carries its own cal coefficients and can be plugged into any compatible meter. At higher voltages, the radius increases; for the 150 kV SmartProbe the radius of the cylinder increases to 48 inches. The user must make sure the probes are plugged into the meter before any voltage is applied.

Like with any probe, rules regarding the location of the SmartProbe must also be carefully followed. Again, the Vitrek 4700 Operator's Manual provides insight into safety guidance. The manual makes this prescription about probe location for the 35 kV SmartProbe:

Full accuracy specifications are valid assuming that there are no objects within a cylinder of radius 18" centered on the probe body extending from the handle (or base) to a point 6" beyond the probe tip. The connection to the probe tip is assumed to extend from the probe tip in line with the probe for at least 6".

Typically, the effect of a hand-sized grounded object is <0.01% at 60Hz when placed 4" from the probe and <0.1% at 400Hz when placed 18" from the probe. As long as objects do not move relative to the probe, there is negligible effect on DC measurements caused by nearby objects. Objects generating fields may need to be placed further away from the probe than these figures.

Handheld Probe Considerations

Most high-voltage meters are capable of making direct measurements with handheld probes for up to 1kV. (As mentioned, advanced meters like the Vitrek 4700 measure up to 10 kV.) In consideration of the hazard potential, use of this type of handheld probe comes with a serious warning, such as this one found in the Vitrek 4700 Operator's Manual:

HIGH-VOLTAGE INSTRUMENTS - ACCURACY & SAFETY CONSIDERATIONS

Handheld Probe Considerations (Continued)

WARNING - THE METER MEASURES VOLTAGES OF UP TO 10kVrms ON THE DIRECT TERMINAL. These voltages can cause severe injuries or death. The user must ensure that connections to these have sufficient insulation for these voltages. Even when sufficient insulation is present, the user should not put any part of their body in proximity to the connections while high voltages are present (at least 1 inch per kV is recommended).

*The user should not insert or remove any connections to the 4700 when high voltages are present.
Warning – do not apply high voltages to a probe without it being properly plugged into the meter.*

WORKING SAFELY WITH HIGH-VOLTAGE INSTRUMENTS

The main goal when working with high-voltage test and measurement equipment is to avoid electricity that can transit through the heart or brain. Per the IEC 61010 standard, anything over 30V is dangerous.

When calibrating high-voltage instruments, it is advisable to set up a safety barrier, such as the fenced-in work area shown in Figure 4. This is an important safety precaution since capacitive coupling can arc as little as three to four feet away.

Additionally, the following steps should be followed:

- Establish appropriate earth ground for all equipment
- Ensure sufficient clearance around all high-voltage areas to avoid unintentional flashovers
- Use barriers or indications for any untrained individuals to avoid potential mishaps
- Ensure voltage is discharged to a safe level prior when making physical adjustments
- Ensure all manufacturers' ratings and recommendations are followed

Workstation and Enclosure

When the test engineer sets up a workstation, it is best to use a remote start switch for either foot or hand. For example, they can use two palm switches connected to an interlock to keep both hands away from energized circuits (Figure 5). They should also:

- Use a rubber mat on the ground and possibly the work bench
- If near an energized circuit put one hand in your pocket or behind your back
- Take off any conductive jewelry
- Post safety signs



Figure 4. Example of a fenced-in work area for testing high-voltage equipment.



Figure 5. Example of a safe workstation set up for high-voltage testing.

WORKING SAFELY WITH HIGH-VOLTAGE INSTRUMENTS

When working with high-voltage equipment, it is also highly recommended that test operators utilize a safety enclosure (Figure 6). Because it is grounded, the enclosure provides safety. When using an enclosure, the test engineer should:

- When possible, use interlocked test fixtures
- Put the device under test (DUT) inside the enclosure
- Remain outside the enclosure at all times
- Periodically test the ground on the enclosure and inspect the high-voltage wiring going from the tester into the enclosure
- Employ optional high-voltage warning light

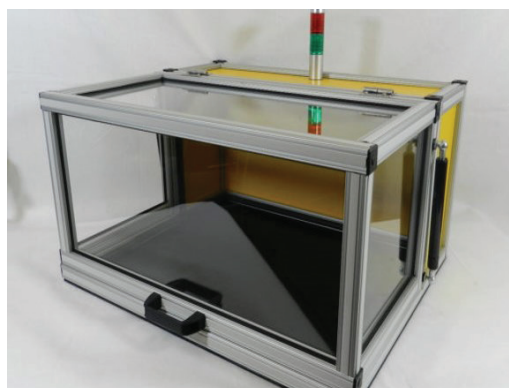


Figure 6. Example of enclosure for high-voltage testing

CONCLUSION

Conducting high-voltage measurements using test and measurement instruments requires consideration to ensure both accurate measurements and the safety of people around the equipment. Compared with using a conventional voltage divider, test operators can improve safety and accuracy by employing Vitrek's 4700 High Voltage Meter and SmartProbes.



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4700 Series High Voltage Meter

Vitrek's 4700 Series high voltage meter offers the highest level of measurement accuracy. It's color touch screen is easy-to-use for set up and display of testing results. Vitrek leverages DSP technology to provide outstanding AC & DC high voltage measurement accuracy, stability, repeatability and resolution. The 4700 offers instant, direct, high voltage measurements in a highly portable, compact and rugged bench top enclosure.



- Measures up to 10 KV right out of the box!
- Expanded measurement options measure up to 140 KV with Smart Probes.
- Chart Mode provides graphic documentation of HV drive ramp time, overshoot and sag.
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