MEDIUM VOLTAGE CABLE TESTING
ARE YOU TESTING WITH VLF?
YOU SHOULD BE. HERE'S WHY.

THREE BASIC METHODS OF CABLE TESTING.

WHICHEVER IS USED, A VLF IS NEEDED.

VLF – TD – PD

DC voltage testing is on it's way out, is out in much of the world. VLF is in. Why DC is out, what is VLF, it's history, it's uses, and its advantages. Let's take a look at VLF and the other methods of testing medium & high voltage cable.

DC VOLTAGE USED FOR DECADES TO TEST CABLE

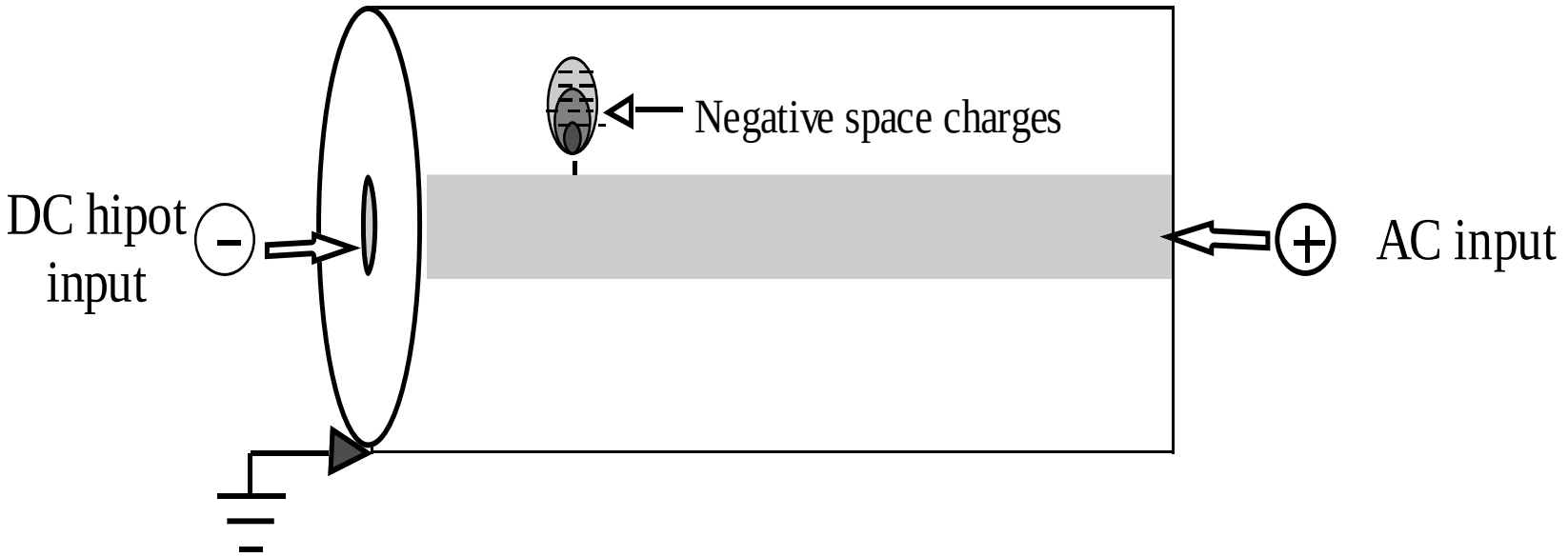
WHY NOT, IT WORKED WELL FOR PILC CABLES, SHOULD WORK FOR SOLIDS, RIGHT?

Wrong: 15 – 20 years after solid dielectric cable was installed, it started to fail prematurely. Testing, research, and field experience has shown that solid dielectric cable is prone to water trees and DC testing at high voltages charges these trees and programs them for failure. Also, leakage currents have been shown to mean little, especially in accessories. Let's find something better.

Q: Can't there be a good AC method for field hipoting cables, like in the factory?

Yes. VLF. Traditional ac power supplies are too big, too heavy, and too expensive, and not portable to test cable in the field. To solve the problem, work on commercial VLF began in the 80's and the use of VLF is now widespread and from many vendors.

WHY DC IS DAMAGING TO SOLID DIELECTRIC INSULATION



DC hipot output negatively charges up water tree areas.

In solid cable, these “trapped space charges” remain after test.

When AC is reapplied, there’s a high difference of potential across very little of the insulation. Leads to pd, electrical trees, & cable failure

WHAT WE KNOW ABOUT DC

PILC & new EPR, XLPE, etc. - DC OK – no space charges

"Service Aged" solid dielectric cable – No DC

Why? Again, "Space Charges" trapped in isolated areas of cable cause high stress points leading to failure & current readings taken by DC proven to be not meaningful

IEEE and most world engineering bodies agree on issue, as well as cable manufactures and cable research labs

DC not compatible with Tan Delta and PD diagnostics

With VLF now reasonable in price and size, why not

WHY IS DC HARMFUL?

WATER TREES ARE CHARGED BY DC

- Tree shaped channels are found within the insulation of operating cables resulting from the presence of defects & moisture in electrical fields.
- Prevalent in solid dielectric cables.
- Eventually leads to PD and the creation of electrical trees.
- Leads to insulation failure.
- DC testing hastens failures.
- **Enter VLF**

WHAT IS VLF?

VLF stands for Very Low Frequency. A VLF hipot has an output of 0.1 Hz and lower rather than 60 Hz. In all other respects, it is just like any AC hipot, and like most AC withstand tests, it is used to provide a go/no-go test, although it can be used for other diagnostic testing. VLF products are rated by their output voltage and their uF rating, or how much capacitance they can test.

VERY LOW FREQUENCY AC HIPOT

A VLF HIPOT IS SIMPLY AN AC OUTPUT INSTRUMENT BUT AT A LOWER FREQUENCY.

THE LOWER THE FREQUENCY OUTPUT, THE LOWER THE CURRENT AND POWER REQUIRED TO TEST HIGH CAPACITANCE LOADS LIKE CABLES AND ROTATING MACHINERY.

DON'T OVERCOMPLICATE IT.

IT'S OFFERS A SIMPLE AC WITHSTAND TEST.

VLF IS THE EASIEST, CHEAPEST, MOST CERTAIN WAY OF TESTING THE AC INTEGRITY OF A CABLE.

DROP THE FREQUENCY
DROP THE POWER NEEDED

Very **L**ow **F**requency: 0.1 Hz and lower.

By decreasing the frequency, it is possible to test miles of cable with a small and affordable unit.

Output frequencies range from 0.1 – 0.01 Hz.

IEEE400.2 recognizes frequencies as low as 0.01Hz.

At 0.1 Hz, it takes 600 times less power to test a cable, or any other high capacitance load, than at 60 Hz. At 0.01 Hz, 6000 times higher capacitive loads can be tested than at 60 Hz with the same power consumption. Basic physics, nothing mysterious.

WHAT A DIFFERENCE THE FREQUENCY MAKES

At 60 Hz. a 1 µF cable has an X_c of 2.65 kOhms.

At 22 kV peak, it requires 8.3 amps of current to test.

Total power supply rating must be 183 kVA.

At 0.1 Hz, the X_c is 1.59 megohms.

At 22 kV, the current needed is 14 mA.

Total power supply needed is only .304 kVA.

(22 kV is the typical test voltage for 15 kV cable)

WHY NOT USE 60 Hz AC POWER SUPPLIES?

A cable has a very high capacitance. A 15kV cable one mile long will be ~1 uF. A 10,000 ft wind farm cable can be 5 uF. To apply a power frequency AC voltage to those loads would require a very high amount of power. The size and cost is nearly prohibitive to use 60 Hz to field test cable of more than a few hundred feet.

HERE'S WHY VLF: Since a VLF power supply generates its output at 0.1Hz, not 60Hz, it takes 600x less current and power to test the same load as at 60 Hz. A 100 lb VLF can do the job of a multi-ton 60 Hz system. Bring the VLF to the test site in your car or the 60 Hz unit on a flat bed truck.

60 Hz. vs. 0.1 Hz.

What a difference the frequency makes

60 Hertz

50 kVac @ 3 kVA

Can test ~ 50’ of cable

0.1 – 0.02 Hertz

40 kVac @ 1.2 kVA

Can test ~ 5 miles of cable

THE EARLY DAYS OF VLF

VLF is used to test high capacitance loads. It was first used to test large rotating machinery: generators and motors. It was first made and used by GE in the late 50's early 60's. ASEA also used VLF around that time. This practice did not continue with the development of the series resonant system used to test high capacitance loads at power frequency.

IEEE433-1974 permits VLF testing generators and motors. The spec calls for 15% more VLF voltage than 60 Hz. It is ideal for rewind shops and field testing.

MORE RECENT VLF HISTORY

Once VLF was established as viable way of testing cables, several companies began work on development. The first to produce a commercially available VLF system was Hagenuk from Germany, now known as Seba Dynatronic. They produced a 54 kV peak/rms system in ~1985. Since this model was rather large and heavy and not portable, it was/is van mounted. Seba has since developed many models, including portable designs. In 12/96 and 5/97 the two German standards for VLF testing oil insulated cable, DIN VDE 0276-620, and PVC cable, DIN VDE 0276-621, were released.

Following Seba was Baur of Austria, who developed their 60 kV peak model in ~1988. It too was rather large and heavy, necessitating a van installation. Both were expensive and caused hesitation in switching from DC testing. Also, DC was not out of favor at this time to the extent it was ten years later. Both developed good products but were a little premature for the market.

MORE RECENT VLF HISTORY

In the mid ’90s, High Voltage, Inc. from NY, developed its line of VLF products, the first being a 40 kV peak model rated for 1.1uF @ 40kV @ 0.1Hz, released in 1998. This model was two pieces with one weighing 72 lbs and the other 50 lbs: the first truly portable system. It was also relatively inexpensive. With this development, and the models that followed, users had a portable and affordable VLF. VLF use was off and running. Shortly after, the IEEE took up writing a standard for VLF testing: IEEE400.2-2004. A revised edition is to be soon released.

Several years later, other vendors have come about, like HV Diagnostics from Switzerland, offering a 30, 60, and 90 kV model.

From all, over the last 10 years, probably 2000 units have been shipped worldwide.

WHERE IS VLF USED TODAY?

Medium Voltage cable is probably 90% of the application for VLF. Long cables with high capacitance need the VLF to test them. It is used by hundreds of utilities, testing contractors, & large industrials. VLF satisfies the need for proof testing newly installed, newly repaired, & any critical application cables. It's also a great splice checker.

Small 30kV models are used to check the integrity of 15 kV cable up to 200kV models to test HV cables. All are also used to provide the voltage for diagnostic testing.

Users have many choices from 4 - 5 vendors, and all the major rental houses in the country carry man models.

VLF FOR CABLE TESTING REVIEW

Original cables were PILC - many oil filled - DC worked well

Solid Dielectrics introduced in ’60’s. DC use continued.

Forty year insulation failing after 15 – 20 years. Why?

Water tress charged up by test, programming cable for future failure & DC leakage currents are not very meaningful

Want to test cables in the field with AC. Enter VLF

VLF permits us to AC field test cables with ease for the first time. Also makes AC diagnostic testing possible

0.1Hz allows testing of miles of cable with portable unit

Distribution systems reliability improving with VLF

SELECTING A VLF

Specs to know before model selection

Must know the cable voltage and test type to select voltage.
    Ex: the Maintenance test on a 15kV cable is 22kV peak.
Must know the cable load capacitance: the uF rating.
Must know the required frequency of test.
Will it be used to Tan Delta and Partial Discharge testing?

VLF Ratings and Selection

VLFs are sized from 20kV – 200 kV. Peak and rms specs.
Models are rated by the uF of load they can test. Ratings from 0.4 – 50 uF.

Most are variable frequency of 0.1 – 0.01 Hz: does spec allow frequencies below 0.1 Hz for withstand testing? For TD & PD testing, 0.1Hz is used. Get a VLF rated at 0.1Hz for the uF rating needed.

Lower frequencies permit higher uF testing. 0.05 Hz can test twice 0.1Hz.

DEFINING THE TEST

The most basic VLF test is a withstand, or proof, test. Apply the voltage for some length of time. The cable either holds the voltage or fails. If it fails, repair or replace and test again. If it passes, the cable is assumed to be good for at least another ~5 years. How better to prove the AC integrity of a cable than to AC hipot it.

The premise of the test is this: if the cable passes a 2 – 3 times normal voltage test, don't worry about. It's good for years. Quite often, the test exposes bad accessories, where poor workmanship comes into play.

We perform AC hipot tests on a go/no-go basis to many loads, now we can do it to cable.

APPLICATIONS FOR USE OF VLF

There are several obvious and common reasons to use VLF.

1. Test after installation. Cable is already de-energized. Guarantee no damage occurred to cable during installation and prove workmanship on accessories is good. Most faults are in terminations, splices, etc.
2. Test after repair. Initial fault may have damaged more cable. Over voltage thumping may have created more faults. Avoid the need for another repair in two months. Often rapid repairs not properly done.
3. Test critical cable on a regular basis. Cause failure when convenient and not during service. VLF failure causes very little damage to cable.
4. Some use VLF to perform a quick check of repaired cable to verify safe to re-energize. Not a full VLF test but a better check than all others.
5. VLF is also used to provide the voltage for diagnostic testing, like Tan Delta and Partial Discharge. (More on that later.)

IEEE400.2 Standard

The IEEE has produced a standard specific to VLF testing that well defines the required test voltages. The time duration for the test is suggested to be 30+ minutes, which has shown to eliminate up to 95% of defects. A 60 minute test may be performed to be nearly 100% assured that no defects nearing failure remain. Following is the chart showing the test voltages. They are generally 2 – 3 times the normal operating voltage. The actual values are determined by the insulation thickness and the desired kV/mm of test voltage stress.

IEEE400.2 FIELD TEST VOLTAGES

For Shielded Power Cable Systems Using Sine Wave Output VLF

	0.1 Hz Test Voltage		
System Voltage phase to phase	Installation phase to ground	Acceptance phase to ground	Maintenance phase to ground
kVrms	kVrms/kVpeak	kVrms/kVpeak	kVrms/kVpeak
5	9/12	10/14	7/10
15	18/25	20/28	16/22
25	27/38	31/44	23/33
35	39/55	44/62	33/47
46 *	51/72	57/81	43/61
69 *	75/106	85/119	63/89

Test voltages are generally 2 – 3 time the line-to-ground system voltage.

* Proposed for next version of standard.

High Voltage, Inc.
VLF Since 1998

CE

28kV

40kV

Mature & well established, durable product line

60kV

Many Models or Custom

200kV

50, 65, & 120 kV

90kV

All Models Can Be Used To Power TD & PD Accessories

As of 2009: >70 countries and nearly 1000 units shipped