VLF TESTING vs. TAN DELTA vs. PARTIAL DISCHARGE
WHICH IS RIGHT FOR YOU?

That is an oft asked question. The answer is easier than you might think. If you can first answer the following question, you're halfway there: **what test data do I want and what do I intend to do with it?** Match the test method and resulting data collected to the desired, and practical, repair approach. Too many times people perform a test without first thinking it through and having an action plan afterward based on the test results. Testing is time consuming and expensive: make sure the data collected is useful and possible to act on. For example: you do Pd testing on direct buried cable and see locations of worrisome Pd. What do you do with that data? Are you prepared to dig a hole where you believe the defect to be, cut out the suspect piece of cable, and then perform two more Pd tests to look each direction from the cut to make sure you got it? Wouldn't it have been easier, quicker, and far less expensive to perform a VLF withstand test? If there's a weakness, let the VLF cause failure, find the fault with conventional fault locators, make the repair and move on. If your cable is critical and you cannot risk failure during the test, then a VLF withstand test is not the right approach. If Pd testing is to be used to rate many cables by severity of Pd, in order to make a hit list of the worst cables to the best in order to prioritize replacement or possible injection, using a TD test to perform the same comparison would be far easier and less expensive and as effective. If a cable is newly installed, the insulation is probably good. PD testing can be used to expose problem accessories or a VLF withstand test to fail defective accessories.

Every method offers useful information. To select the right approach, or multiple approaches, it is what you plan to do with the information collected that must be decided first.

Explanation of the three methods of testing. Which to use when and where?

A Very Low Frequency high voltage AC tester is used to perform a withstand test. A VLF instrument is relatively inexpensive, very easy to use, and quite portable, depending on model. VLF models are available from 20 kV to 200 kV and in many power levels. They output 0.1 Hz to 0.01 Hz and are rated by the capacitance of the load they can test. Models available can test from 3000' to 30 miles. IEEE400.2-2004 defines VLF testing methods and the voltage levels and time duration for each MV class of cable.

A VLF test will cause a failure at any defect location severe enough to be triggered into partial discharge under the test voltage. Enough test time is allowed to grow the defect to failure. Find the fault with conventional fault locators, fix it, and retest to check the repair and to find additional defects. If there are no additional failures, you know that cable is good for years. If several failures occur in the insulation, it is advisable to stop testing and mark the cable for near term replacement. If a cable is in conduit and all that is necessary is to find which length is bad, the VLF test is the best way to go. There is no need to use the far more expensive and complicated PD detection method, for you don't care precisely where the fault is since you're going to pull and replace a few hundred feet of cable anyway. If the goal is to test many cables but without the risk of failure, then the VLF is not appropriate. Use either the PD or TD approach to rate your cables by severity of deterioration to help prioritize replacement, injection, or other tests. The VLF is used as the voltage source for these diagnostic tests. A very good use of VLF testing is to verify the AC integrity of a cable following repair. Also, after installation is an obvious use of VLF. The cable is already de-energized; test is to verify installation and possible poor workmanship. A PD test is far too complicated and expensive and unnecessary for the situation. Just VLF it! Wind farm cable testing is a perfect example of where to use a VLF withstand test.

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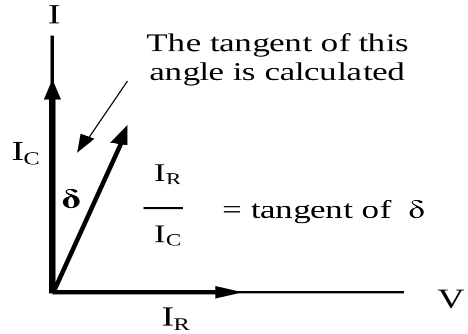
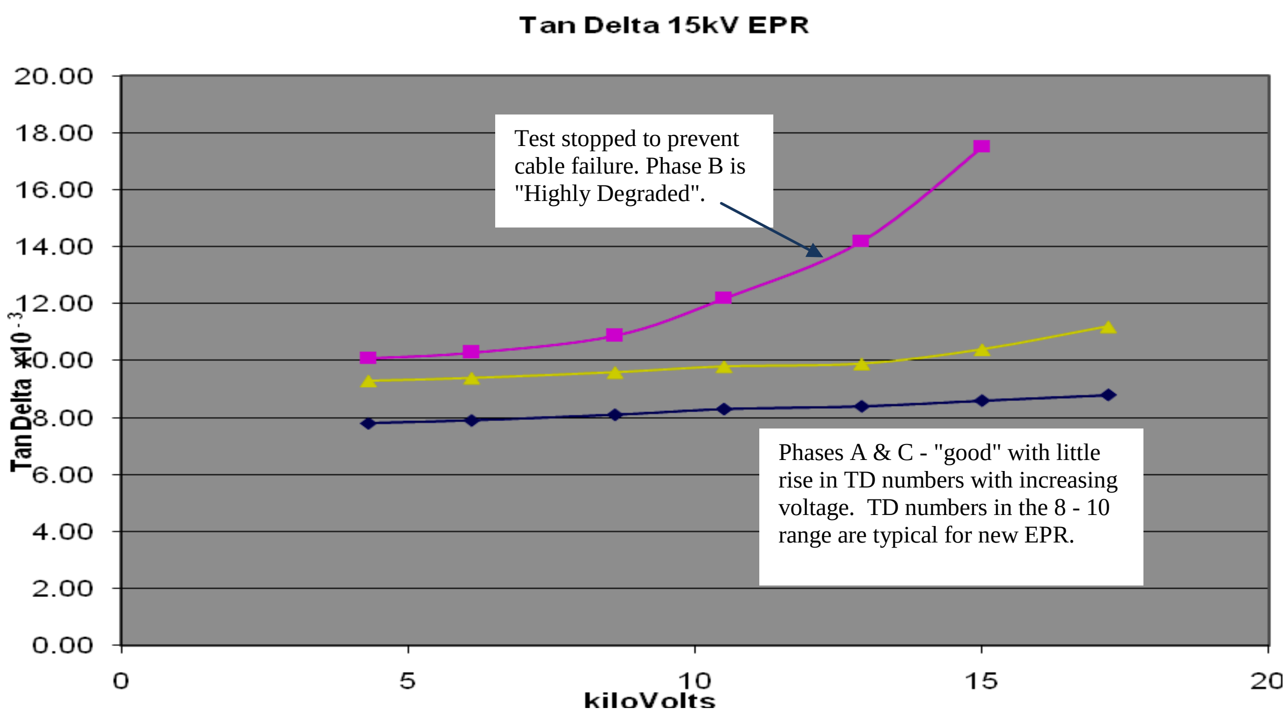
Tangent Delta testing, sometimes shown as Tan δ, provides the user with an overall condition assessment of the cable. It is also called Dissipation Factor or Loss Angle testing. The test is performed on a cable to learn the condition of the cable from start to finish. It does not show individual defects along the cable, **it shows only the condition of the total cable**. The test is relatively simple to perform and the results are not difficult to analyze. This is an off-line test with the cable disconnected at both ends. A VLF is used to provide the variable voltage for the test while the TD instrument takes the measurements. The test is most useful as a comparative test, where many cables are tested, evaluated, and ranked from bad to good, or Highly Degraded, Slightly Degraded, Good. Some rate the cables by Action Required, Further Study Required, and No Action Required. This rating helps the user prioritize cable replacement, repair, silicon injection, and possibly what other tests may be useful.

If a cable is in perfect shape, it simulates a capacitor. With perfect insulation, the capacitive current is 90° out of phase with the applied voltage. The more deteriorated the insulation, the more this angle is less than 90°, as a resistive element is added to the circuit. It is this angle that is measured.



The VLF is used to apply the voltage, usually up to 2Uo, or two times the normal line to ground voltage. As the voltage is raised to capture perhaps 5 or 6 test points, measurements are taken. The TD numbers measured are important but the shape of the curve as the voltage is increased is more important. In a perfect cable the graph is flat, indicating there are no major defects: the cable is good. If a cable is highly deteriorated, the graph will trend upwards as voltage is increased. The cable is not a pure capacitor, as it has a resistive element to it due to defects. The worse it is, the higher the graph trends.

It is used to provide a comparison of several or many cables to select the ones to fix first. It is useful to test cables in conduit and replace the worst ones since is easy to do so. If a cable is direct buried and not easy to fix, and a VLF test is not preferred since it may cause failures, then a tan delta or a partial discharge test is the better way to go.



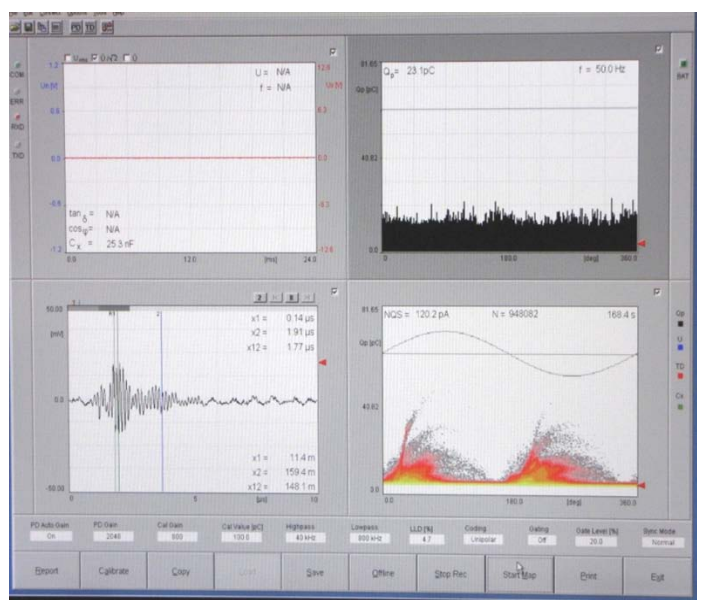
Off-Line Partial Discharge testing is used to identify cable defect locations and their severity**.** Pd testing and especially analysis of results is far more complicated than what is described here. Having said that, Pd cable testing technology has advanced to the point where it is fairly accurate in its determination of location and severity of cable flaws. What is described should be sufficient to know enough about Pd testing to make an informed decision of testing options.

Opposite from the TD test that grades the overall cable quality, Pd hopes to show discreet locations of electrical discharges. Once identified, the user can make a decision as to whether the level of discharge is acceptable or not. That interpretation and ambiguity is the trick that makes Pd testing more difficult compared to the other testing methods. That is not say it does not have value, it does, but in choosing any test method, ease of use, meaningful data gathered, and cost must be balanced against the usefulness of the data gathered.

Pd is just that, a partial discharge in a localized void, moisture pocket, or some other defect that creates an imperfection in the insulating material. Under voltage stress, the defect discharges energy. It is a partial discharge because it is in a localized area of the insulation and does not bridge the insulation between the live conductor and ground, causing a total failure of the material. Left to continue discharging, it will spread through the material until the insulation is compromised enough that the voltage stress causes a total failure. Pd testing not only locates the defect and measures its severity, through a variable over-voltage supplied, it also shows the voltage level where Pd starts and where it extinguishes. This is very useful data to show how close to line voltage a potential fault may be.

Whether a Pd test makes sense, the method of cable repair should be known. If the test is used to compare many cables and spend your money repairing or replacing the worst first, then a Tan Delta test is a better choice since it less expensive, easier to perform, and less interpretive. However, what must be remembered is that a TD test shows the overall quality of the insulation. Even if it looks good, there still may be one or two effects that may fail but do not influence the TD numbers over the entire length of cable. If the application is sensitive, then a Pd test may be desired to find out the potential for failure. Having said that, if the budget for repair is limited and will be used up on the worst cables and not reach down to the moderate or slightly deteriorated cables, then the TD test alone is sufficient. As said earlier, an analysis of the total job, the method of repair, and the money and time available, must be performed before making an intelligent decision as to what test procedure is best.

This screen shot is an example of what the Pd measurement and analysis display looks like. It may look complicated, and is, compared to the tan delta method, but once learned, it does provide valuable data. The location and amplitude of the Pd are shown, and to some degree, the type of defect can be learned. Apparent from the data displayed, it takes a good deal of knowledge and interpretation to make the best use of the test results.



PD testing is a useful method of determining one aspect of a cable's condition. It is the best method in certain circumstances. The cost of the test, knowledge of the operator, ease of the test, and ability to interpret the results all play into whether this will be performed or something else. Maybe this and the TD test will be used. With some VLF systems, both features are included.

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Summary

VLF withstand testing is useful for causing failure at defect locations, usually splices and terminations. This is advantageous for testing de-energized cable after installation, after repair, or when a critical cable can be made available, if the user is prepared to make the repair or replace the cable. The VLF causes very little damage to the cable when an arc occurs. Convention fault locating methods are used to locate the fault. A VLF withstand test is the easiest, least expensive, and most conclusive method of testing. VLF hipots, depending on voltage rating, are now portable and affordable. Sizes are available from 20 kV – 200 kV. HVI has shipped nearly 1000 units to over 70 countries. An IEEE standard exists for VLF testing: IEEE400.2-2004. There are also several international standards.

VLF Tan Delta testing is a very useful method for evaluating the level of deterioration in a cable. Most uses are to test many cables and rate them by levels of degradation. Once done, the user now has a hit list of which cables to start with for replacement, repair, injection, and/or other tests that may be useful. Although one limitation is that the same cable type should be used in the test circuit, it is still a very useful method. It is easy to use and requires little interpretation. Tan Delta and VLF units are readily available from most equipment rental houses.

VLF Partial Discharge testing is the newest of the methods now available. Pd testing of cable has been done for many decades, but usually in the factory at power frequency. It has been found that Pd detection at 0.1Hz is similar enough as 60Hz and is generally accepted. Even if it isn’t exactly the same, it doesn’t matter, for all we are looking for are locations of worrisome discharge. With the advent of portable and affordable VLF products, it is now possible to perform the test in the field. Although the interpretation of the results, especially on accessories, can be somewhat problematic, it is still a useful test for finding weaknesses in cable systems without causing failure.

Conclusion

All three methods of testing provide useful information, but different information. None are suited for every situation. None can provide all the information needed about a cable system. An analysis of all three technologies and the data they provide should be performed before making a decision. The cost of the test, the cost to buy the equipment, the ease of the test, the ease of interpretation, the skill of the operator necessary, the availability of the equipment, the cable design, age, ease of repair, the data needed to make cable maintenance decisions, and whether cable failure during the test is permissible are all vital in selecting what is best for your cable system and situation.

Don’t believe any vendor if they tell you only their method is meaningful. All three work, just pick the right one for your situation, or all of them.

Much has been written on all three methods of test. A very good source of information that helps summarize the topic is the work of NEETRAC at Georgia Tech. They have just concluded a five year study to provide an extensive and unbiased evaluation of all three methods. Phase 2 is about to begin to take their research further. On their web site there are several papers and PowerPoint presentations they authored and are available for download.
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