



# Increase Productivity By Increasing Reliability

Cable Testing and Fault Locating for Wind Farms



## Background Information

Testing the condition and integrity of the underground cable system on a wind farm is key to ensuring the reliability of the entire system. One cable failure in a wind farm collector system can result in **tens of thousands of dollars** in lost revenue. Since the underground cable system is the backbone of the wind farm the health of that system must be monitored and checked. The best way to make sure that the wind farm's underground cable system does not have a failure is to test the cable with a proven method which will reliably indicate the condition of the cable. The question then becomes what is the best type of test and when should the test be conducted.

Cable tests and diagnostics can be categorized in several different groups. Test methods can be either local or global and can offer results which are either preventive or predictive. The type of test that is required depends on several factors which are unique to each individual system. The age of the installation, the length and size of the cable in the system, the physical layout of the cable system, the type of cable in the system are all factored into what type of cable testing is needed.

Circuit designs for collector systems which have no isolation points create an especially difficult problem when fault locating and cable testing. Due to the length of the cables in systems of this design, the energy required to test or fault locate is very high. Many cable failures are also the result of the installation practices of the underground cables. As more and more wind farms are constructed and as the existing wind farms age, the reliability of the cable system becomes more and more essential to the overall performance of the electrical system.

## CABLE TESTING FOR NEW INSTALLATIONS

New installations of cable require localized testing. Since the cable itself is tested at the factory before delivery, the testing of installed cable is preformed to identify localized problems which could have occurred during installation. The most likely locations for defects are splices and terminations, and the cable sheath.

### Sheath Test

The sheath test is the first test which should be preformed after the cable has been installed. This test is preformed to indicate whether there has been any mechanical damage to the outer cable sheath during installation. If the outer sheath has been damaged the degradation of the neutral and of the cable insulation will be imminent which will result in premature cable failure.

### VLF Test

VLF (Very Low Frequency) testing is done to prevent an in-service cable failure. The VLF test is a "go/no go" proof test. The unit applies a voltage (typically 1.7 to 3 times the operating voltage) to the center conductor of the cable. For new installations the test is completed to verify the integrity of the workmanship (splices and terminations).

### Partial Discharge

Partial Discharge testing is a predictive test method designed to inform the owner of any problems in the cable which may cause future failures. The test is a non destructive method which will identify locations in the cable which exhibit an electrical discharge (measured in coulombs). The test will identify the intensity and the location of all partial discharges at weak spots of a substantial nature on the cable. Depending on the level of partial discharge the owner can make an informed decision on whether to repair the cable or keep the cable in service. This test is one which requires interpretation of results which is best gained by experience.



## CABLE TESTING FOR EXISTING CABLE SYSTEMS

For existing installations the condition of the cable itself requires testing along with the splices and terminations. Over time the cable itself can develop imperfections in the insulation. Cable testing on aged cable systems has been proven in the utility industry as an effective method of improving overall system reliability. By having a preventative maintenance testing program, defects in the cable which were minor in nature when installed, but have since gotten worse, will be detected. By testing the cable the owner can proactively manage the cable system, thereby avoiding costly emergency outages.

## VLF Test

For aged cable, which can develop water trees and electrical trees, the test acts to test the entire cable and will push to failure the weakest critical location on the cable



## Partial Discharge Testing

Partial discharge testing for existing cable systems has a two fold function. The first function is identical to the function for testing a new cable installation. The owner is attempting to discover locations along the cable where there is a partial discharge. The second function is one of comparisons. By comparing PD levels from previous tests the owner can complete a trending analysis of the cable. If there was a certain PD level that was observed in the cable that was deemed acceptable by the owner during a previous test, that location should be tested again. If the PD level has remained unchanged then the cable can be left in service. If that PD level has risen then the location of the PD should be isolated and repaired to avoid a costly outage.

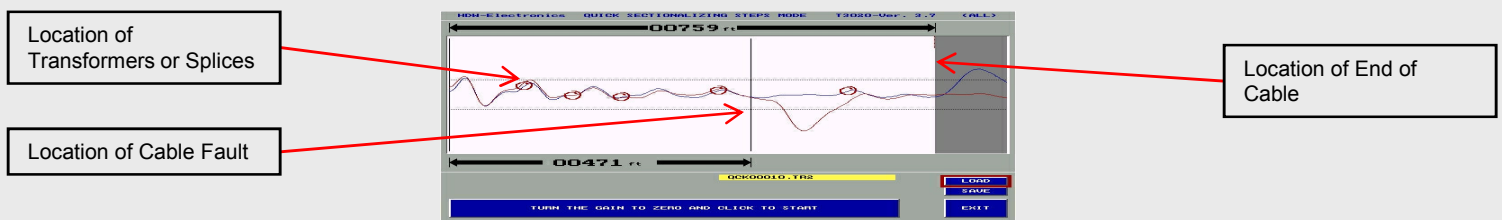
## FAULT LOCATING:

When trying to determine the correct fault locating equipment for a wind farm there are many questions which need to be answered:

- What is the largest cable size that will require fault locating?
- What is the longest cable that will require fault locating?
- Can the cable be sectionalized?
- Are there branches in the cable system?

The answers to these questions will determine the type of fault locating system that is required for the wind farm. The most important factor in determining what type of fault locating system to use is the capacitance of the cables being tested. The larger the capacitance of the cable, the larger (more voltage and energy) the thumper needs to be able to supply. **The surge capacitance of the thumper must be considerably higher than the capacitance of the cable.** The cable capacitance is a function of the size and length of the cable. Typically, the longer and larger in diameter the cable, the greater the capacitance (actual capacitance values are available from the cable manufacturer). If the thumper does not have enough capacitance the probability of finding a fault in a long length of cable is severely diminished. The problem with using a thumper that is not powerful enough is a real safety issue. In order to find a fault on underground cable a surge generator (thumper) is attached to the cable. The surge generator sends a pulse of electricity through the conductor. When there is a fault on the cable the pulse of electricity causes an electrical arc at the location. This arc creates a noise (thump) in the ground. The location of the thump is the location of the fault. The problem with a thumper that is not powerful enough is that it will not create enough energy to create the arc. The voltage that is applied to the cable is stored in the cable. When the cable reaches its capacitance, the voltage stored in the cable is reflected off of the far end on the cable and back fed into the thumper causing a catastrophic failure in the thumper. Because of the long runs of cable in many collector systems this issue is one that is common to many wind farms.

The surge generator however, is only half the required equipment. Along with the surge generator the fault locator will need a cable radar (Time Domain Reflectometer) in order to locate the fault quickly. When the radar is used in conjunction with the thumper the fault locator can get an accurate distance to the fault. With extremely long runs of cable the radar is a tremendous time saving device that will cut hours out of restoration times.



# Products Glossary for Cable Testing and Fault Locating on Wind Farms

## MMG10 MVG5 ESG80



HDW offers the MMG10 unit to complete the sheath testing function. The MMG10 is used to apply up to 10kV of voltage onto the cable neutral. If the sheath is not damaged the neutral will “hold” the voltage and show no leakage current. If there is any damage to the sheath the voltage will drop and the MMG10 will read leakage current. The location of the sheath fault can be determined by prelocating the distance to fault using the MVG5 high voltage bridge and can be pinpointed using the ESG80 earth fault locator.

## VLF



HDW offers VLF testing units in voltages ranging from 20kV to 80kV. For very long cable runs with very high cable capacitances HDW’s VLF units offer the highest testing capacitance at 0.1Hz of any VLF on the market today.

## OWTS



HDW offers the OWTS partial discharge system which used a damped AC voltage to test the cables. The system test the cable at a power frequency (50Hz to 300Hz) which is one of the approved test methods outlined in IEEE 400.3. The system supplies testing voltages up to 250kV which allows testing for all distribution cables and most transmission cables

## PVS100



The PVS100 is a phase verification system which can be used to verify phase angles anywhere on the electrical system. The system is used whenever there is a need to identify a phase. Whether that need arises due to phase rolling, mismarking, or as part of the connection to the utility transmission system, the PVS100 will correctly identify the phase.

## SG25-1150M



This portable thumper is designed for cable systems that can be sectionalized where isolated pieces of cable with relatively short runs (less than 1 mile) are the system design. The unit consists of a two voltage range surge generator (0-12.5kV and 0-25kV) and a 25kV DC hipot. When combined with the T3050 cable radar this fault locating system is the perfect solution to a cable system which can be sectionalized.

## SPG40-2000J



The SPG40-2000 is really the ideal fault locating system for most applications. It offers several different methods of fault prelocating including Arc Reflection, Surge Pulse, Decay Plus, and Sheath Locating. It also offers a powerful burn function along with a two voltage range (0-12.5kV or 0-16kV and 0-25kV or 0-32kV(optional 0-8kV range)) surge generator which can locate faults on cables with lengths up to 5 miles. The unit is fully integrated with the radar controlling all functions.

## SWG1750-CDI



For wind farms with extremely long cable lengths (10 miles or longer) the SWG1750-CDI is the fault locating unit of choice. With 3500 joules of energy and 32kV this unit is able to locate even the highest resistance faults. The unit offers three voltage ranges (0-8kV, 0-16kV, 0-32kV) with 3500 joules on energy available in each range. It also offers a 32kV DC hipot. When paired with the T3050 radar with extended range (100,000') this fault locating system will find fault on even the longest of cables.

## INTEGRATED SYSTEMS:

The **Centrix system is a fully integrated fault locating and testing “tool box”**. The system provides six different fault pre-locating methods along with fault pinpointing and sheath testing for power cables. A VLF and OWTS test system can be integrated. Only one hook-up is required for all of the various testing and locating options. All system controls are completely isolated from the high voltage compartment

