The Trillion Dollar Cable Question!

A trillion dollars is likely a conservative estimate when you consider the magnitude of the power cable issues in the U.S. It has been known for some time that the cable systems in the U.S. have reached and in many cases exceeded their life expectancy. Let’s face it, wholesale replacement of an underground cable installation is expensive, time consuming and many times results in off hour scheduling and clearances requiring customers to be without power during reconnection of power to the installation.

A lot needs to be said about the aging power cable issue and much has been published involving the failures in cables, splices and terminations. Analysis clearly states the issues with service aged polyethylene (XLP) concentric neutral cables that were the main stay for utility installations in the 60’s through 80’s. These cables, thought to be the answer to many installation issues, turned out to be a “major disaster,” considering reliability and replacement costs. Much of this type of cable was of the concentric neutral (CN) design and had no jacket to protect it from the environment or from installation damage. Enter “water,” the culprit of the century where XLP insulation is concerned. In defense of the manufacturers and utility engineers, no-one knew what was to ensue between water and Cross-Linked Polyethylene insulation i.e. the formation of water trees in the insulation. Since this condition is slow to develop and much slower to lead to total insulation failure via the formation of full blown electrical trees, it was not evident early on that these 40 yr. cables would only last half of that time, with many only lasting 10 to 15 years before failing. Tree Resistant Cross Linked Polyethylene (TRXLP) came on the scene in the late 90’s for most utilities and this treeing issue will largely go away over time for the most part. Most utilities are keenly aware of this issue today and are in the beginning or middle stages of providing “high tech” rejuvenation processes that extend the cables life or are planning complete replacement of these cables in bulk quantities at significant costs.

Utilities and industries with large cable systems are currently at various stages in addressing the issues with service aged XLP cables. Two topics keep coming up in the industry discussions that are very important in addressing this major concern. One is “Condition Based Maintenance” and the other is “Diagnostic Testing”. Both of these topics are extremely important, considering the costs incurred with cable replacement. The third item that is addressed in this paper is the “human factor,” to be defined in later discussion.

First, let’s discuss Condition Based Maintenance. I recently met an engineer in a large utility that was given the overall management responsibility of a $150 million cable replacement project. This is a large opportunity for the possibility of a huge success or it could result in financial disaster without a planned approach that involves a condition based maintenance philosophy. Some of the concerns one should have involving the cable maintenance issue are:

1. How much cable are we talking about? 10K feet? 100k feet? 500k feet?
2. What kind of cable, when installed, what size, voltage, etc.?
3. What is the history concerning the cable plant?
4. What is the mode of construction? Direct bury, in conduit, aerial, duct systems, etc.?
5. Ultimate cost of materials and labor!
6. Are labor forces available with competent cable personnel?
7. At what point in the life cycle is the cable under consideration? This is a big question!
8. What methodology is going to be used to determine condition and priority of replacement?

These are a few of the questions that have to be considered concerning cable maintenance. These items deserve infinitely more detail considerations than discussed here. Our objective is to point out the importance of the Condition Based Maintenance philosophy concerning cable maintenance rather than itemize it.

This brings up the second topic of discussion, Diagnostic Testing, and it concerns the “condition” term in the maintenance topic. For years, cables have been proof tested for acceptance and maintenance tested employing an age-old technology known as the D.C Hipot. This technology has been used for decades to test and retest cables utilizing laminated paper insulation (PILC) and has proven very successful. This technology is inexpensive, easy to use, and appeared to be the logical choice to continue to test new and service aged cables of the extrude XLP design. This approach proved to be the wrong choice through the efforts of the Electric Power Research Institute (EPRI). EPRI concluded that service aged XLP cables that were already in the stages of insulation tree formation would develop “space charges” that remained in the insulation after testing and when reenergized with line frequency, could hasten to failure. This was a significant revelation in the cable industry as at that time there wasn’t a proven alternative and no industry consensus standards providing alternative guidelines for testing. Many companies halted testing in any form and cable systems new and service aged went without any acceptance or maintenance test at all. Enter the “Dark Ages” for cable testing.

Today, however, we have current industry standards (IEEE 400 Bundle Series and NETA) providing guidelines for withstand (acceptance) tests and diagnostic tests for troubleshooting, trending and diagnosing cable condition. These new testing technologies come at an opportune time and for the most part, evolved due to the need to diagnose the condition of service-aged cables in the U. S. and other countries with the same cable issues. Due to the issue using Direct Current test voltages as previously discussed and the requirements for using 60 Hz line frequency for testing high capacitive cables of long length, Very Low Frequency (VLF) has become a popular test technology. VLF is used to perform withstand (acceptance) proof tests as well as Dissipation Factor (VLF Tan Delta) diagnostic tests. VLF Tan Delta used in conjunction with the Partial Discharge test has proven to be a successful method in analyzing the condition of service aged extruded dielectric cables (XLP) and not causing any further deterioration of the insulation.

There are numerous manufacturers in the U.S. and other countries manufacturing all manner of test units to perform diagnostic testing. Industry consensus standards support the technologies and provide guidelines for utilities and industries in the U.S. to administer effective testing programs to address the complex issues concerning underground power cable installations. The test method applied and the specific equipment is usually dictated by how the information will be used. The size of the cable system and the effect of the test data concerning reliability and cost ultimately dictate conditioned based maintenance decisions.

The complexity of the new testing technologies, evaluation of test results and importance of sound installation practices brings us to the final topic of discussion, the “Human Factor”. Considering the cost and the importance of our electrical systems in the U.S., we have to ask ourselves this question:

“Where, in all of the plans and technology improvements for our cable systems have we provided for the safety, technical and skills training for our human resources?” Good question considering the millions of dollars being spent on new cable, new technology, new test equipment and methods. With all the planning and technical issues to address concerning the cable issues at hand, it’s easy to overlook the one resource that is going to ensure the same mistakes are not made that will continue to plague us over and over in the future.

The NEETRAC Studies point to the major causes of cable failures in the U.S. being tied to poor workmanship issues during cable pulling, splicing and terminating. This being true and well documented, it is reasonable to expect without a change in direction, the same results will repeat itself. The millions of dollars spent in insulation rejuvenation, cable replacement and re-splice and terminate will not have the positive effects in service reliability, revenue and reduced costs that are expected. The outcome will be dismal and ultimately the workmanship issue will be revisited where cable installation is concerned, and as experience tells us, at much higher costs.

Ensuring excellence in workmanship and proper application of the technologies for cable installation and testing requires significant training and demonstration for workers involved in cable maintenance.

One of the most important aspects of cable work is the absolute requirements for safety. Workers are routinely involved in working on power systems that were or possibly could become energized. Many times the technician will be working in one section of switchgear and adjacent switchgears on either side will still be energized. Most of the high voltage and high power test equipment used in withstand and diagnostic testing of power cables can produce lethal shock, thus requiring significant safety precautions to be taken in order to ensure the safety of all workers either involved in the testing or in the area where testing is being performed. OSHA 29 CFR 1910.269 (o) Testing and Test Facilities provides regulations for workers involved in high voltage and high power testing. OSHA further mandates that employees have to be trained prior to performing this type of work. There are numerous other regulations and standards related to maintenance and testing of power cable systems that have to be incorporated into the safe work practices and training for working on or near power cable systems.

Training in proper cable handling, splicing and terminating of power cables is a necessity or the same failure modes will reappear in the future. It’s been said in the industry many times that about 90% of integrity of a splice or termination is in the “cable prepping”. Many of the splice or termination failures occur because of inappropriate cable prep, either by misapplication of the products, tools or some human error in removing and dimensioning the cable layers. Modern splicing Kits come with detailed instructions as to what the process is, but do not provide the experience in performing the steps in the kit instruction that are needed to be successful at splicing. Splicing and terminating power cables is a craftsmanship issue and has to be addressed with a significant hands-on experience mentored or instructed by very competent cable personnel. There is a significant effort currently in the U.S. in large utilities as many of their experienced cable personnel have retired and are no longer available to provide the much needed mentorship to junior personnel involved in cable maintenance. Ramping up cable splicing training, certification, and demonstration of skill and testing technology is a necessity moving into the future where reliability and cost of maintenance are sure to be issues.

Diagnostic testing using a Partial Discharge Test set and software to analyze the test data is a long way behind in technology from a megohmeter test and a D.C. Hipot test. Test technicians have to be trained not only in all the safety aspects of the job, but in the technology of the test and how to use the test equipment as well. Not only is Diagnostic Testing an issue, but cable fault location as well, due to technology enhancements in that type of equipment and the constraints of locating faults on service aged XLP cable systems.

In summarizing the discussions above, we must consider all aspects of a well-planned Condition Based Cable Maintenance Program. It is imperative that the cable plant be analyzed to determine the condition of the cable systems. The service aged XLP cables installed during the 60’s through 80’s have to be examined and tested to take corrective action as needed. Cables have to be tested and prioritized according to condition, using the latest in Diagnostic Testing Technologies. Using test data and cable experience, we are able to make decisions concerning replacement, rejuvenation and just re-splice and terminate.

One of the most important parts of the overall cable puzzle is the human factor. It doesn’t make good business sense to install millions of dollars of new cables, purchase expensive test equipment and repeat the same workmanship issues only to experience the same types of cable failures in the future.

Safety of personnel is the most important factor and significant attention has to be provided for personnel involved in high voltage and high power testing. Safe work procedures, personal protective equipment, live line tools, personal protective grounds and work area protection are only a few of the items that require training.

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