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A REVIEW ON FAULT ANALYSIS IN UNDERGROUND CABLES

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ABSTRACT

This project evaluated underground cable failure and researched innovative techniques for diagnosing failing underground power distribution cables. The aging of installed underground distribution cables is a looming issue facing electric utilities in India. A variety of technologies and tests are available for evaluating underground Cables, but there is often little correlation between what is diagnosed and what is found when the cable is pulled out and examined. The project team studied various cable failure mechanisms to better understand failure causes and to identify improved failure detection methods. Researchers investigated novel online techniques for detecting the degradation of concentric neutrals and insulation in the cable. Water trees are defects in high voltage cables that are the result of moisture content or the permeability of water within the insulation. The results suggested that both chemical and mechanical forces drive water tree creation. The injection of charges from electrolytes that form around a submerged cable can also contribute to water trees formation. Researchers concluded that two proposed diagnostic techniques were most promising: magnetic amorphous magneto resistive concentric neutral probing and radio frequency test point injection techniques.

Keywords: Underground Cable Diagnostics, Water Trees, Online, Insulation Diagnostics, Concentric Neutral Diagnostics, Magnetic Field Sensing.

I. INTRODUCTION

This project examined the problem of underground cable failure and researched using problematic at best. The failures of underground power distribution cables represent a serious threat to the reliability of electric power infrastructure. Replacement must be done selectively, since cable replacement is very expensive, per kilometre (km) of cable in an urban area. The two goals of this project were to use novel approaches to determine the degradation mechanisms of underground power distribution cables and to develop innovative online techniques for probing the integrity of underground cables without needing to take the cable off‐line.

II. UNDERGROUND DISTRIBUTION CABLE

The aging of installed underground distribution cables is a looming issue facing electric utilities in India. Over 100,000 miles of underground power distribution cables are installed . Replacing all of the cables is infeasible from an economic point of view and hence diagnostic techniques are needed to determine which cables need to be replaced first. The structure of a typical underground distribution cable is shown on Figure 1. The cable consists of a central conductor (CC), made out of aluminium or copper, and covered with an inner layer of a semi conductive polymer called semicon . The semicon layer is encased in an insulted material such as polyethylene (PE). The insulator is covered with an outer layer of semicon . A set of spiralling concentric neutrals (CNs) are positioned on top of the outer semicon layer. Newer cables typically have an outer jacket of PE extruded over the CNs .

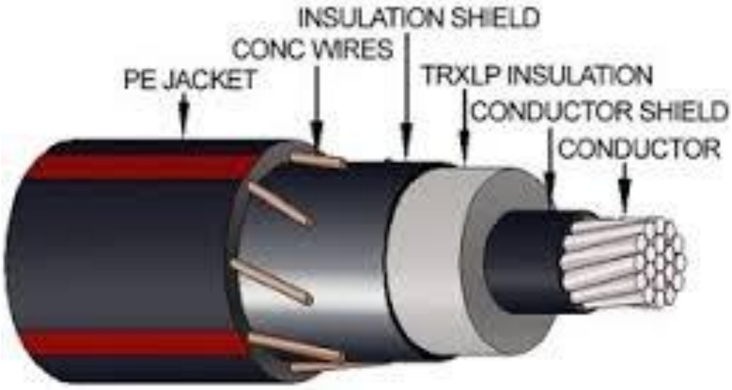

Figure 1: The Structure of a Typical Underground Power Distribution Cable

III. PROJECT OBJECTIVES

The objectives of this project are to two fold:-

a) To use novel approaches to determine the degradation mechanisms of underground power distribution cables,

b) To develop novel online techniques that probe the integrity of the underground cables without the need to take the cable offline

IV. HOW A UNDERGROUND POWER CABLE SYSTEM AGES , DEGRADES AND FAIL

There are following reason why a underground power cable degrade and fail :-

1. Manufacturing imperfection
   - Voids
   - Contaminants in insulations
   - Poor application of shield material
   - Protrusions on the shields
   - Poor application of jackets
2. Poor workmanship
   - Cuts
   - Missing applied components or connections
   - Misalignment of accessories
3. Aggressive Environment
   - Chemical attack
   - Transformer oil leaks
   - Floods
   - Petrochemical spills
   - Neutral corrosion

4. Wet Environment
   - Bowtie trees
   - Vented water trees
   - High rates of corrosion
   - Can reduce dielectric properties
5. Overheating
   - Excessive conductor current for a given environment and operating condition(global)
   - Proximity to other cable circuits for short distances (local)
6. Mechanical stress
   - Damage during transportation (usually localized)
   - Excessive pulling tensions or sidewall bearing pressures (can be localized or global)
   - Damage from dig-ins (local)
7. Water Ingress tends to reduce the dielectric strength and increase the stress in the area surrounding the moisture.
   - Normal migration through polymeric materials
   - Breaks in seals or metallic sheaths

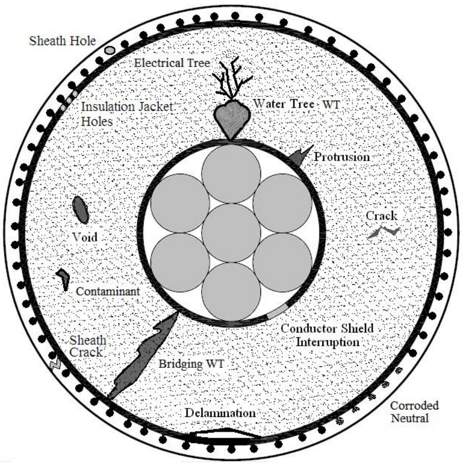

Figure 2: Typical Power Cable Defects

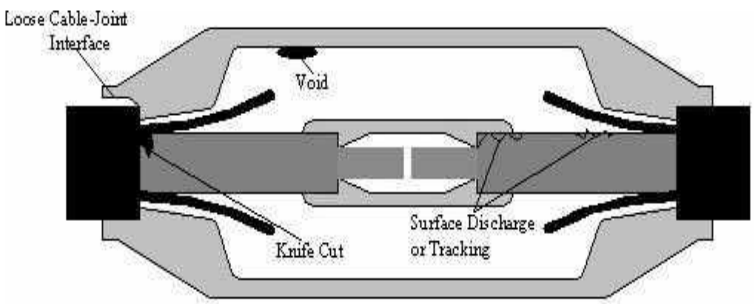

Figure 3: Typical Cable Joint Defects

A major cause of failure in underground power cables is the formation of water trees that lead to electrical trees. The latter are conductive pathways between the central conductor and the concentric neutrals (or ground)

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through the polyethylene (PE) insulation separating the two. The former are micro cavities connected by yet smaller channels and filled with water or an aqueous solution. As the water, being more conductive than the surrounding PE, increases the field near the extremities of the water tree, there is eventually electrical breakdown of the PE and an electrical tree is formed, rapidly destroying the insulation and cable. Water treeing appears to have been first described by Kitchin and Pratt (1958) and has been the subject of numerous investigations. Figure 4 shows a picture of a cross ‐ section of an underground distribution cable with visible water trees.

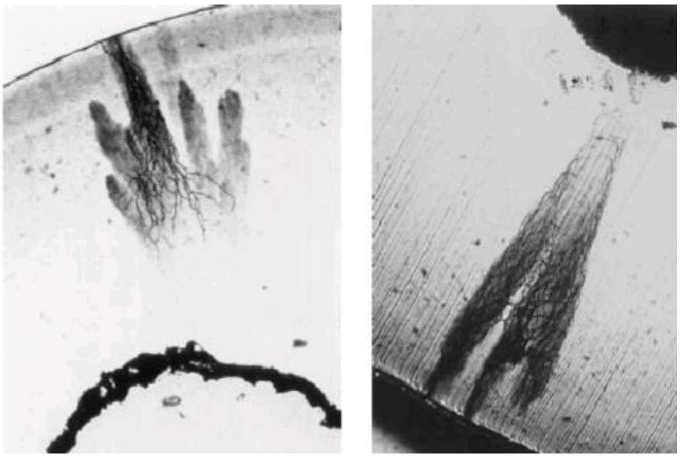

Figure 4: Water Trees in the Insulation of Underground Power Distribution Cables

Water trees are degradation structures in a polymer that:

1. Are permanent,
2. Have grown due to at least humidity and an electric field,
3. Have a lower electrical strength than the original polymer when wet, but which are not a short circuit or local breakdown path, and
4. Are substantially more hydrophilic than the original polymer

Most investigators have fallen into one of two schools of theory in explaining the formation and growth of water trees:

• the chemical school believing that the PE interacts with water (omnipresent in the earth or conduits in which the cable is laid) in a mechanism which likely involves electrochemical or electrical phenomena, or

• the mechanical school believing that stresses, arising as the cable is manhandled during installation or from dielectrophoretic forces, are large enough to cause propagation of the channels and voids of the water trees. There is, of course, the possibility that both chemical and mechanical phenomena play a role in water treeing.

This part of the investigation probed the phenomena of water treeing with the belief that the resistance of materials to degradation can only be increased if the mechanisms of degradation are understood. Three topics were examined through a combination of experiments and theoretical work, including mathematical modelling:

1. The thermodynamics of water treeing. Earlier distinguished work had suggested that the chemical potential (propensity for reaction) of chemical species in water trees would be greatly increased by the strong electric field in the insulation to the point where tree formation and propagation was driven by this enhanced chemical potential.

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2. The fatigue failure of PE under cyclic loads that can be generated by electrophoretic forces. These forces arise when materials with different permittivity (such as, PE and water) are within an electric field. In the case of cable insulation these forces would cycle at 120 Hz (twice the 60 Hz of the AC power).

V. RF TEST-POINT INJECTION TECHNIQUE

5.1 Introduction

It is well known to the power utilities that imperfections known as water trees can develop in the insulation of power distribution cables. Starting from imperfections in the cable insulation, the imperfections may grow due to electromechanical or chemical forces (Maxwell stresses) until they ultimately cause a destructive arc discharge in the insulation that renders the cable unusable. As the water trees grow, they affect the permittivity and conductivity of a cable's insulation, causing changes that might be helpful in detecting badly water ‐ treed cable that should be replaced to avoid explosive failures. But replacement must be done selectively, since cable replacement is very expensive.

One of the main goals of this research was to evaluate novel techniques for detecting water trees in energized underground power distribution cables, for use in condition ‐ based cable replacement methodologies. So we introducing RF probing signals into a functioning energized cable by using the test points found on the elbows used at both ends of underground cable conduits. Researchers will describe the generally accepted water tree characteristics, the possible use of the cable test points for cable probing, and the auxiliary equipment needed for such testing. Researchers will also describe the processes and difficulties of obtaining water trees for experimental study, and methods for measuring both RF signal loss and phase velocity of propagation in cables designed for power distribution at 10 to 60 kV and 50 Hz or 60 Hz.

5.2 Experimental Setup

For two ‐ ended detection (Figure5), researchers would couple to the test points at both ends of the cable, launch an RF wave from one end and measure its amplitude at the second end to find the attenuation due to one transit of the cable. For this test, a spectrum analyzer can be used as a narrowband RF detector. Determining the RF phase velocity from the signal at the far end may be possible using a procedure analogous to the resonant

Figure 5 : Two-ended Cable Test Setup Utilizing the Test Points to Launch and Receive the RF Probing Signals

VI. PROJECT RESULTS

we use and analysis of an RF (radio frequency) probing signal that was injected into a functioning energized cable by using the so‐called test points found on the elbows of cable conduits. The hypothesis was that water trees in the cable could be detected by measuring both the attenuation and the velocity of propagation of the signal as a function of the instantaneous line voltage. It was shown that a signal can be successfully coupled to an energized cable; however this method did not yield positive results on a section of an in‐house aged power distribution cable. The reason for the lack of positive result may have been due to failure to produce water trees during the in‐house aging process; therefore this technique may still be promising, albeit dependent upon further investigation.

The transmission of an RF signal through an energized power distribution cable was successfully demonstrated. The lack of a positive result from this method, for example, the detection of failure sites, is believed to be attributed to the lack of a properly aged cable with water trees for testing.

6.1 Project Benefits

The deterioration of very old installed underground distribution cables threatens the reliability of the electric power infrastructure in India and elsewhere. The lack of effective technologies and tests for evaluating the stability of these cables makes it difficult for electric utilities to diagnose problems without removing and examining cables. Replacing the cables can be extremely expensive. The innovative research conducted in this project investigated several key failure mechanisms in the insulation of underground power distribution cables. The project's results can help electric utilities diagnose these issues more effectively, which will increase the reliability of the electric infrastructure in India.

VII. CONCLUSION

The lack of a positive result from this method, for example, the detection of failure sites, is believed to be attributed to the lack of a properly aged cable with water trees for testing. Then investigation of this method should be continued once a suitable water - treed cable has been found.

REFERENCES

[1]. Boggs, S., "On - axis Field Approximations for a (Semi -)Spheroid in a Uniform Field," IEEE Transactions on Dielectrics and Electric Insulation, Vol. 10, pp. 305–306, 2003.

[2]. Das Gupta, D. K. and R. S. Brockley, "A Study of 'Absorption Currents' in Low Density Polyethylene," Journal of Physics D: Applied Physics, Vol. 11, pp. 955–962, 1978

[3]. Hvidsten S., E. Ildstad, J. Sletbak and H. Faremo, "Understanding Water Treeing Mechanisms in the Development of Diagnostic Test Methods," IEEE Transactions on Dielectrics and Electric Insulation, 5(5), pp. 754 - 760, Oct. 1998.

[4]. Koo, J. Y., J. D. Cross, M. El - Kahel, C. T. Meyer and J. C. Filippini, "Electrical Behaviour and Structure of Water Trees in Relation to their Propagation," Annual Report Conference on Electrical Insulation and Dielectric Phenomena, IEEE Publication 83CH19831902 - 6, pp. 301 - 306, 1983.

[5]. Seidel, M., I. Paprotny, R. M. White and K. Krishnan, "AMR Current Sensors for Evaluating the Integrity of Concentric Neutrals in In - Service Underground Power Distribution Cables," Conference Record of the IEEE International Symposium on Electrical Insulation (ISEI 2010), June 6–9 2010.