Leakage Detection of Water Distribution Network in Shallow Ground using Electrical Resistivity Principle

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Abstract **- Water is a daily necessary resource for life, health, economic development, and the ecosystem all over the world. As water is precious to everyone, its availability and quality are essential. Wastage of water due to pipeline leakages is one of the most critical and largest challenges confronted throughout the globe. Water is considered to be one of the vital resources used around the world. And most of the countries highly depend on the standard of water management. Sustainability of available water resources has now become a dominant issue for several reasons. The issue is quite related to poor water allocation, inefficient use and absence of good enough and integrated water regulation. Therefore, wastage of water due to pipeline leakages is one of the most critical and largest challenges confronted throughout the globe. Previous few decades many tracking gadgets integrated with water leakage detection have been common. Monitoring water leakage is a necessary responsibility for government and residence prospect. Thus, from an engineer's aspect, distribution of water can be enhanced mainly by limiting the water waste that occurs along the path, between the source and the end-users. But leakages are unavoidable due to some circumstances, such as corrosions manufacturing defects and aging of pipes**

When leak occurs in pipelines, large volume of water is lost, causing adverse impact on the production industries and common people's routine. Since the pipes are invisible and Unreachable, indication of cracks is not noticed. Hence finding the leakages and replacing the defective pipe is very crucial during the distribution of water and gas. Therefore, Implementation of pipeline leakage detecting system has importance in domestic applications and industries. The existing leak detecting systems such as acoustic waves system, ground penetrating Radar (GPR) systems, pressure measurements, fiber optic monitoring and vision-based systems etc. are based on measurement of acoustic waves, radar waves, pressure, of needed lots of labor efforts and erroneous measurements of leaks would lead to expensive Repairing of the ground. Therefore, by a possible system is to be built, that can effectively detect the leaks in the pipeline to minimize human intervention.

Index Terms **- Leak detection, Resistivity principle, groundwater exploration, detection and location, leakage, pipe burst, water distribution system.**

INTRODUCTION

A water distribution system should supply necessary amount of potable water at demand points for domestic, commercial, industrial and firefighting purposes; the system should be capable of meeting the stress almost any time at required pressures.[1] However, sometimes considerable water leakages from the system may because problems associated with the pressures at the consumers tap and significant water losses. Leakage is defined as the amount of water which escapes from the pipe network by means other than through a controlled action. [2] Water leakage in distribution systems is typically classified into background and burst related leakage. Bursts (i.e. main breaks) represent structural pipe failures and background leaks represent the water escaping through inadequate joints, cracks, etc. Leaks can also exist in service reservoirs and tanks. [3]

The unaccounted flow of water and leakage within the water supply system and the urban water distribution network are paid attention in many countries. Leakage occurs in all water distribution systems nowadays. Scientific and systematic planning of the water distribution system can help to reduce the leakages. Initially the factors causing leakages should be identified and subsequently the leakage management methods can be adopted. A significant amount of water is lost in the water supply system. Water leakages have been a major problem for many regions around the world (Weifang et al, 2011). [4] In some countries water loss due to water leakages in the

supply network exceeds 40% of the water in the supply system. Traditional field survey methods are costly and time-consuming, as the timely identification and monitoring of leakages in the water supply network is a very complex task (Huang et al. 2010). Over the years, different non-intrusive techniques have been used to monitor and identify water leakage.

1.1 Objective

Surface electrical resistivity surveying is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivity and distribution of the surrounding soils and rocks. The usual practice in the field is to apply an electrical direct current (DC) between two electrodes implanted in the ground and to measure the difference of potential between two additional electrodes that do not carry current. Electrical Resistivity Survey is performed by passing a known electric current into ground by means of two current electrodes and the potential differences between the other two potential electrodes is measured.

LITERATURE REVIEW

Physicists are finding that the skills they have learned in their training may be applied to areas beyond traditional physics topics. One such field is that of geophysics. This paper presents the electrical resistivity component of an undergraduate geophysics course at Radford University. It is taught from a physics perspective, yet the application of the theory to the real world is the overriding goal. The concepts involved in electrical Resistivity studies are first discussed in a general sense, and then they are studied through the application of the relevant electromagnetic theory. Since geology majors comprise the bulk of the students in this class, the math used is only that which is typically required of geology majors.

The laboratory sessions that accompany these courses are usually designed to illustrate a specific concept, using table top equipment designed specifically for that lab. In this paper, the electrical resistivity section of a course in geophysics taught at Radford University is described. The application of the techniques of physics to the study of field geophysics yields a natural arena wherein several of the basic concepts of physics may be integrated into a single area of study. Several topics in electromagnetic theory are illuminated in this study including the vector form of Ohm's law, the nature of the current density vector J, the nature of electrical resistivity and its inverse electrical conductivity, and the difference between the electric potential and the electric field.

Electrical prospecting involves detection of surface effects produced by electrical current flow in the ground. Electrical resistivity method. Induced polarization (IP) method. Self-potential (SP) Method. (EM) method. Electrical Resistivity Survey is conducted to investigate the subsurface resistivity distribution beneath an area of interest. General, an electric current is injected into the ground, and the resulting voltage differences are measured at the surface of the Earth. True resistivity of the subsurface can be estimated from this voltage measurement.

It has been reported that the amount of non-revenue water reaches. These losses can be classified into unbilled public usage, consumption and metering inaccuracies, and real losses through overflows at storage tanks and burst leaks in distribution pipelines caused by bad connections, pipe corrosion, and physical damages. It is especially very important to detect the burst leaks in buried water pipes in order to reduce water production costs as well as to protect public safety.

METHODOLOGY

There are many methods to acquire soil resistivity measurements, but the most common are the Wenner and Schlumberger methods, also called the four-pin methods. Regardless of the method, the general concept can be described as injecting a known current into the soil and measuring a voltage. The following figure represents the current flow and the equipotential lines produced by a current that is injected through the ground with two different soil layers.

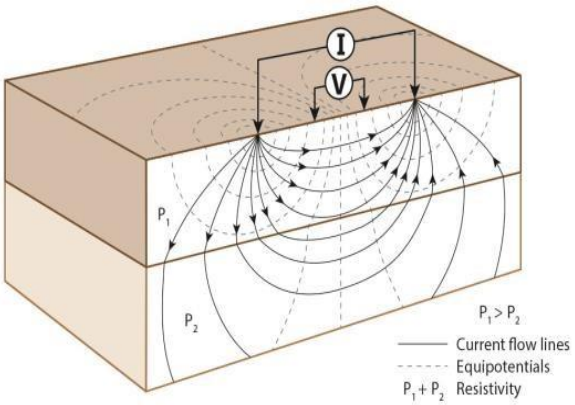
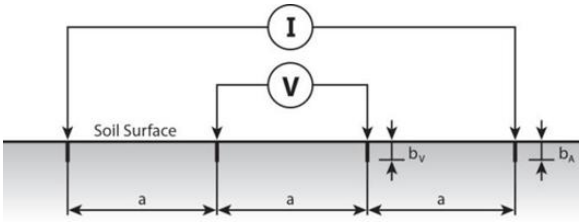


Chart -1: Methodology flow chart

Wenner Method

The Wenner alpha four-pin method is the most commonly used technique for soil resistivity measurements. It is performed by placing four pins at equal distance, injecting a known current on the outermost electrodes and recording the voltage between the interior electrodes. The following figure illustrates the Wenner alpha four-pin method.



If the depth of the probe, b << a, as is the case of electrodes penetrating the ground only for a short distance (as usually happens), the apparent resistivity can be calculated as follows:

$$\rho_E = 2\pi a \frac{V}{I}$$

Using the Wenner alpha method, the electrode spacing is increased along a path to measure greater depths of soil. This is possible because, as the electrodes spacing is increased, the test source current penetrates greater areas, in both vertical and horizontal directions, regardless of how much the current path is distorted due to the varying soil conditions. Smaller electrode spacing measurements, shallower measurements, are important to characterize the soil with which the grounding system will be in contact. Longer electrode spacing, deeper measurements, are typically taken such that the maximum spacing between pins is equivalent to the maximum dimension of the grounding system to be evaluated. If the resistivity varies appreciably with depth, it is often desirable to increase the range of electrodes spacing to assess the resistivity.

Schlumberger Method

In the Schlumberger method, the distance between the voltage electrodes "a" and the distances from a voltage electrode and a current electrode "c" are different (see figure).

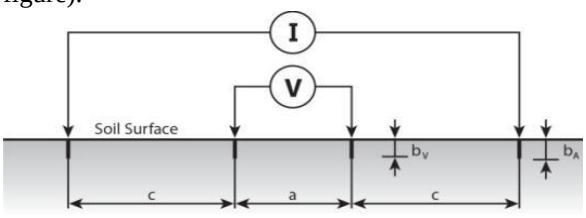


Fig.

If b << a & b << c (as usually happens), the apparent resistivity can be calculated as follows:

$$\rho_E = \pi \frac{c(a+c)}{a} \frac{V}{I}$$

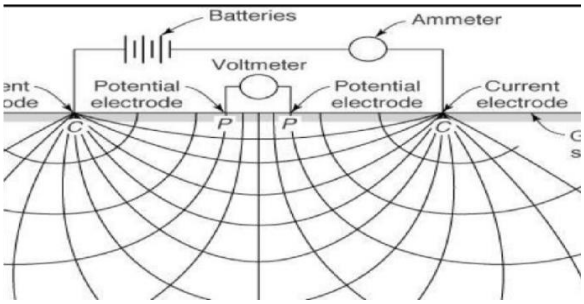
The configurations with a > c is known as the "Schlumberger – Palmer method" while the configuration with a < c is known as the "Schlumberger method." Compared to the Wenner method, the

Schlumberger method is less laborious because it does not require the interior voltage electrodes to be reinstalled for each measurement. The Schlumberger method is also advantageous in that shorter measurement cables, smaller free space, and less time are needed to conduct the testing to acquire resistivity measurement of equivalent depth to the Wenner method.

Compared to the Wenner method on equal terms, using the Schlumberger method with c > a requires more sensitive instruments because the measured resistance is lower, while with c <a measurement may be easier with a greater measured resistance.

Type of Soil	Resistivity Range (Ω-m)
Clay	15-150
Loam	15-100
Sandy Clay	50-300
Sand	200-3000
Gravel and Sand	500-5000
Solid Rock	10000+

Procedure for leakage detection



By using one of method of resistivity principle

a. Wenner Method
b. Schlumberger Method

In this process a known value of electric current (I) is passed into the ground by two outer metals stakes that are buried in the ground. The potential variation (V) is measured between two inner electrodes termed potential electrodes (ρ1and ρ2). The ratio of V/I provides the resistance (R) and by multiplying R with the geo-electrical factor (K) of the electrode separation, the resistivity 'ρ', and it is inverse of conductivity of the ground may be described.

(The soil resistivity value is subject to great variation, due to moisture, temperature and chemical content.)

In this process a known value of electric current (I) is passed into the ground by two outer metals stakes (C1 & C2) that are buried in the ground. The potential variation (V) is measured between two inner electrodes termed potential electrodes (P1and P2). The ratio of V/I provides the resistance (R) and by multiplying R with the geo-electrical factor (K) of the electrode separation, the resistivity 'ρ', and it is inverse of conductivity of the ground may be described.

Depth can calculated by following formula:

Depth of investigation =1/3 of AB Spacing

RESULTS AND DISCUSSIONS

Formulation of Specimen Soil System and its Electrical Resistivity calculations; The Current is injected in to the Specimen Soil System using two outer electrodes (C1 & C2). Additionally, two inner electrodes (P1 & P2) are used to measure the potential difference (voltage) due to injected current electrodes (C1 &C2). These measurements of Current & Voltage are done by using Digital Multi-meters.

CONCLUSION

The following conclusions can be get based on the results and discussion presented previously

- Resistivity of the soil decreased rapidly with an increase in the leakage duration.
- The soil resistivity was found to increase with an increase in the depth/distance from the liner leak. This observation can be used to localize the leak position in the liner

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