Ohm's Law & Utility Locating

The relationship between electrical current (amps), resistance (ohms) and power (watts) and the effects of each on utility locating.

How to locating better through understanding the effects of electrical current and resistance.

Abstract

Using electromagnetic locating instruments to locate metallic utilities requires establishing an electrical current flow in a loop circuit on the target utility. The result of the current flow is a magnetic field of the same frequency impressed on the utility. A transmitter applies the current to the utility and a hand held receiver picks-up the frequency and displays strength of the magnetic field (signal strength). A technician using the instrument is actually locating the magnetic field and not the pipe or cable, this is fundamental and sets the foundation for better locate operations. A strong magnetic field is the direct result of higher current flow on the utility being located, resulting in the instrument displaying a higher signal strength. Higher signal strength is the fuel that runs the locating receiver's engine making the utility locate easier and more accurate. Higher signal strength is also inversely proportional to the resistance in the circuit created when directly connected to the utility.

This paper will attempt to explain the relationship between better utility locating and understanding the elements, current, resistance and watts of Ohm's law.

Georg Ohm formulated the relationships between voltage, current and resistance that can be expressed mathematically as I = V/R. "I" represents current. Why he used the letter I is confusing, possibly the letter C was taken. The letter R represents resistance and logically then V represents voltage. Using this formula Mr. Ohm was able to prove that current in a circuit is directly proportional to the applied voltage and inversely proportional to the resistance in the circuit. There is a chart of Ohm's and Watt's law at the end of this paper.

Consider this experiment using a garden hose connected to the faucet. Water pressure in the hose represents voltage. When the faucet is turned on the water pressure is constant and the flow of water, representing current, in the hose is proportional to the water pressure. When the water pressure is reduced so is the water flow in the hose, increase the pressure increases the flow. The same is true in an electrical circuit. When resistance is applied to the garden hose while the water pressure remains the same, what happens? Resistance can be illustrated by pinching the hose. What happens to the pressure in the hose? As resistance is applied the pressure remains the same and the flow is reduced. Thus, as resistance (R) is increased, flow (I) is reduced illustrating the inverse proportionality. Now carrying these basics to utility line locating.

In utility locating a circuit must be established through the connection of one transmitter lead to the metallic utility and the other to an earth return or ground spike. A loop circuit is established. Voltage from the batteries of the transmitter is regulated to a constant.

This produces a constant (I) current that is inversely proportional to the resistance in the circuit. Let's analyze where the resistance in the utility locate circuit comes from and what can the technician do to reduce it. Consider the elements in the utility locate circuit for a moment. The utility (pipe or cable) adds resistance as a function of the material it is made of and the earth return accounts for another major resistance factor. Every few feet of water pipe a dielectric (plastic/rubber) gasket is located adding even more resistance to the current flow. Breaks and nicks in the insulating jacket of a wire conductor also increase the resistance on wire conductors (optical fiber sheath, electrical power lines or telecommunication cable). The locate tech cannot change any of the resistance inherent to the utility; this is just not practical. The tech can however change the earth ground connection or increase voltage from the transmitter. Let's take the earth ground connection first as this is easiest to change and has a profound effect on current flow in a given circuit.

Keeping in mind that the transmitter is applying a constant voltage to the utility through a direct connection, the only efficient and economical way for the technician to increase the signal strength of the magnetic field is to improve the earth return connection. Fortunately there are numerous methods to improve the earth return or ground, most are quick, easy and very low cost. The focus of improving the earth return in the utility locate circuit should be either increasing the surface area of metal used as the earth return or increasing the conductivity of the earth around the focal point of the earth return (ground spike). More metal in the ground results in less resistance in the circuit at that point and the best way to get more metal in the ground is simply step on the ground spike and push it all the way into the earth. Many times in our rush to set up a locate the ground spike is only inserted part way. Yes this makes the spikes removal a bit easier but results in a greater resistance than necessary and with a simple action as stepping on the spike.

Should the ground spike prove to be insufficient, a more radical yet simple approach is available. Looking around the locate area you commonly will see metallic posts, fences and the like. All these have much greater metal to earth contact than the standard ground spike and if applied properly will significantly reduce the resistance in the locate circuit, resulting in higher signal strength. To connect the ground lead, usually black, to one of these earth returns a ground extension wire may be necessary. Whatever the method, connecting to a metal fence or street sign post will greatly increase current flow and should become a regular method of connection where line resistance is high.

Caution must be taken when using a metallic fence or extending a ground lead over other utilities. Insure any fence used to improve the earth ground connection is not parallel to the utility being located or the receiver may see the current flow both on the utility and the metal fence. By maintaining a significant distance between the fence and the utility will minimize any distorted or confused signals. Care must also be taken when extending a ground wire as the wire may induce a signal onto a utility unknown to the technician. Using high frequency on a locate will increase the potential of induction or bleed-over to unwanted utilities causing a mislocate situation.

When fences and metal posts are unavailable and the earth is very dry the technician has other tricks to improve the signal strength. Two very easy methods present themselves, bring more metal to the area, wet the earth or both. Having a roll of aluminum foil in the truck is always a good idea when the locate area is remote and the soil is dry. To increase the metal surface area, simply scrape a furrow in the soil, strip off a length of aluminum foil and firmly place the foil in contact with the soil in the trench. Wetting the soil under the foil will greatly help. Attach the ground lead to the foil; toss dirt on the foil for better soil contact and you have an improved earth return. Wetting the soil is another excellent method of improving current flow and signal strength. Plain water is really all that is necessary, however here is a mixture that goes one better.

Recipe for Locate Water

1 Gallon water
2 Tablespoons of table salt
2 Tablespoons of liquid dishwashing liquid (Dawn)

Secure top to water container and mix well.

For cold climates where water may freeze replace the water and dishwashing liquid with commercial automobile windshield washing liquid. This mixture reduces resistance by wetting the soil (dishwashing liquid) and increasing conductivity (water and salt). Tests have shown as much as a 20% reduction in resistance at the ground spike by applying this solution. Don't knock-it till you've tried it.

With this understanding of resistance and current there is one additional point to consider that is, power in Watts. A lot can be said for power, more power can help improve the current to a point where an exceptionally deep pipe can be located or push the distance of a locate in the miles instead of feet. The relationship of power to current however is not proportional, that would be much to easy, in fact the relationship is such that twice the power does not result in twice the current. The mathematical formula can be expresses as $P=I^2*R$ or put another way, the doubling the power results in the square of 2 of current or 1.4 times current. What is the significance of this you say? Everyone considers more power is better, in fact while it does improve the current is does so inefficiently which usually means cost increase. Cost increases in battery usage or wasted as heat in the transmitter. Here the old saw more is not always better holds true for power especially when the FCC limits power use at certain frequencies.

This discussion would not be complete if frequency and inductance were not briefly mentioned. By using methods to improve current on the utility increases the magnetic field and this may cause what is commonly referred to as: bleed-over and bleed-off. These two are different and are a function of frequency and current strength (signal strength). Bleed-over involves the capacitance of two metallic utilities in close proximity. When a strong magnetic field intersects an adjacent metallic utility, some of the magnetic field is induced on to the adjacent line. This is called bleed-over, as in the magnetic field bleeds over on to the adjacent pipe or cable. Bleed-over can cause

mislocates because the technician may mistakenly begin following the second conductor. By reducing the current on the line or by changing to a lower frequency or both may reduce bleed-over to an understandable and manageable part of the locate. High frequencies have greater inductance capability and with stronger magnetic fields become very efficient at bleeding-over to other lines.

Take for example the 104.5 MHz of a local radio station with a 50,000 Watt transmitter. The high frequency has excellent induction characteristics especially when pushed with all that power. The antenna on your vehicle "picks-up" the signal through induction, which is why the greater distance you are from the transmission tower the weaker the signal. The exact same physics govern the induction of a high frequency signal onto adjacent lines. The remedy is lower frequency and lower power.
Everyone knows of the FCC, Federal Communication Commission. This governmental body regulates the electromagnetic spectrum used in telecommunications as your locating instrument in you hand. At higher frequencies the FCC restricts cable locators from emitting more than 1 Watt of output power. Now one Watt of power may not sound like much, but the inductive characteristics of higher locating frequencies don't need much to bleed-over. Lower frequencies are allowed to have higher power output because they do not readily induce onto adjacent pipes and cables.

A cousin to bleed-over is bleed-off, fortunately they are very different and their effects are easily recognized. As current flows along a pipe or cable it returns to earth to complete the circuit mentioned earlier. Utilities that are in direct contact with the earth have the greatest bleed-off, while insulated cables have the least. Bleed-off results in shorter locates and "ghosting" or the representation of a magnetic field that is not truly present. Shorter locates are indicative of significant bleed-off and can be reduced by switching to a lower frequency. This may not always be possible if a higher frequency is required to jump gaskets on a water pipe.

Higher frequency generally offers greater current flow resulting in greater signal strength. And as mentioned along with these improvements come increases in bleed-over and bleed-off. On the other hand, lower frequencies reduce bleed-over and bleed-off with the lower signal strength. However longer locates on insulated cable are attainable, some as long as 10 – 30 miles depending on the power output applied.

Using this knowledge will help improve utility locating, by giving the technician the fundamentals to make good decisions. Knowing what variables can be changed to improve signal strength or how to recognize bleed-over and react by changing frequency are decisions that make for more accurate productive utility locating. When the focus is on signal strength and reducing resistance in the loop circuit will offer up the best results and depending if the locate area is congested or not frequency selection will become an important variable for a quality locate.

Putting this altogether, a closed loop circuit is required for current flow, direct connect whenever possible. Make a choice to reduce resistance in the circuit buy using that fence or signpost. Have a ground extension reel with at least 100' of wire at your disposal and

make up a gallon or so of the locate juice. When in congested areas use lower frequencies where possible to reduce bleed-over and manage power output for the best locate. Low power and low frequency are excellent selections to begin any locate. More power is not always better unless the cable is well insulated and low frequency is used for maximum distance.