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Current and Voltage Calculations On Cable Shields In Substation Zones-Of-Influence

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Harold C. Held
Telcordia Technologies
6200 Route 53
Lisle, IL 60532
630-960-6276
email: hheld@ameritech.net

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CURRENT AND VOLTAGE CALCULATIONS ON CABLE SHIELDS IN SUBSTATION ZONES-OF-INFLUENCE

Abstract – General-use telephone cables that pass through an area subject to Ground Potential Rise (GPR) will pick up current from pedestals or ground rods and carry current along the metal shield to remote ground locations. This paper will review the electrical principles involved in this model and will demonstrate the use of a computer spreadsheet to calculate current flow on a cable shield and the voltage to remote ground along the shield.

I. ELECTRICAL PRINCIPLES

Assume that 10 amperes of current flows through a ground electrode into the earth as shown in Figure 1.

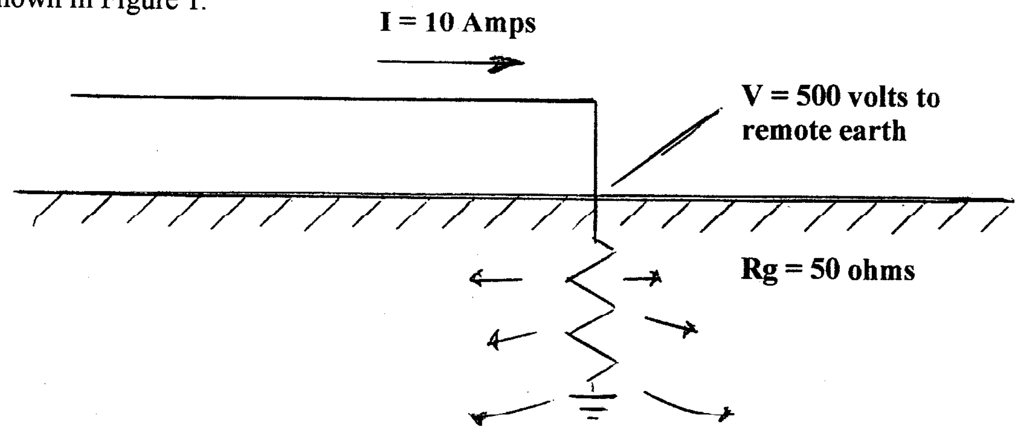

Fig. 1. Simple Example of GPR

If the resistance to remote ground of the electrode is 50 ohms, there will be a voltage drop of 500 volts across the soil around the electrode, which we call GPR.

Now assume that there is a 600 volt source in the earth, driving current up through the earth and along a conductor (cable shield) that connects the electrode to earth at a remote point. This is illustrated in Figure 2.

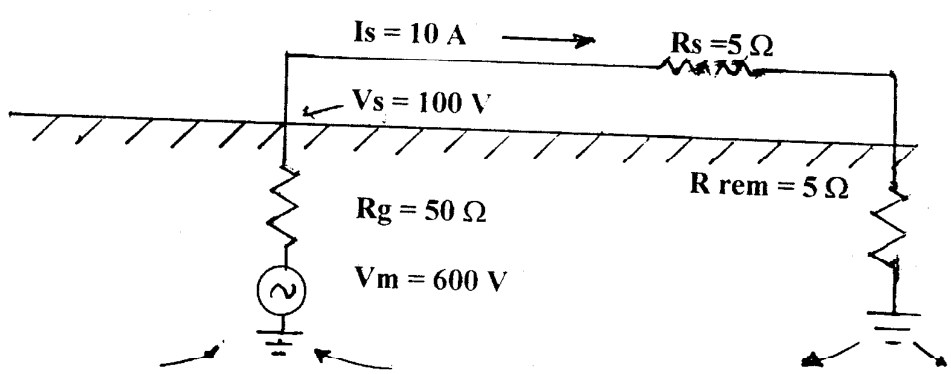

Fig. 2. Source Voltage in the Earth

If the electrode resistance is 50 ohms, the conductor or cable shield resistance is 5 ohms and the resistance of the connections to earth at the remote location is 5 ohms, then 10 amperes will flow in this circuit. The voltage of the electrode or shield to remote ground will be 100 volts, a value considerably smaller than the 600 volt GPR at that point.

Another way to visualize the transfer of potential from one electrode to another, when the two are mutually coupled, is shown in Figure 3.

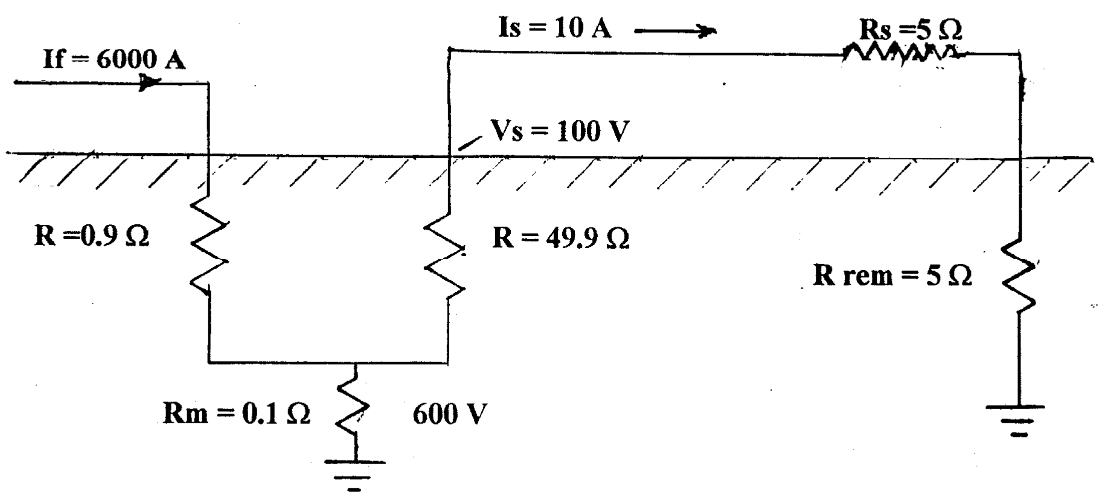

Fig. 3. Transfer of Potential

Continuing this example, 6000 amperes of fault current flows through an electrode having 1-ohm resistance creating a 6000 volt GPR. At the 600-volt point, a ground rod or pedestal has 50-ohms resistance to remote earth, of which 0.1 ohm is mutual resistance. Again, 10 amperes flows through the earth, through the electrode, and along the cable shield (5 ohms) to a remote ground electrode (5 ohms). The voltage of the cable shield to remote earth at the pedestal is 100 volts (10 amperes * 10 ohms).

2. TELEPHONE DISTRIBUTION CABLE

A telephone distribution cable entering a substation zone-of-influence will likely have several connections to earth where current will enter the cable shield during a fault. The shield current and voltage can be calculated using functions on a computer spreadsheet. A sketch showing ground locations, GPR at those points and cable shield resistances should be made, as shown in Figure 4.

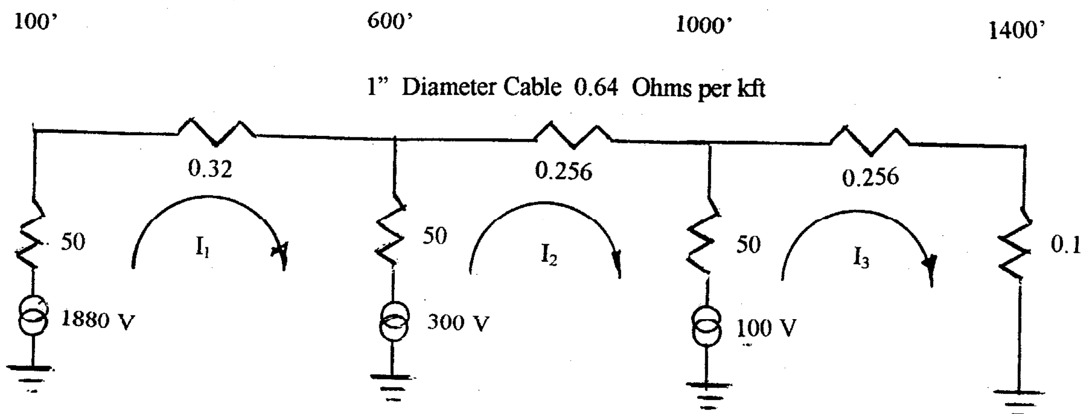

Fig. 4. Circuit Diagram in a Zone-of-Influence

Equations using Ohm's law can be written, and current flow on the cable can be calculated using the matrix functions of a spreadsheet. Knowing the values of current, the voltage to remote earth at each pedestal can be calculated. In Figure 4, if I_1 is 36.8 amperes and I_2 is 42.2 amperes, the pedestal voltage at the 300 volt GPR point (600 ft. from the substation) is 300 –50(42.2-36.8) = 30 volts.

A more general case is shown in Figure 5, where the distribution cable passes by a substation at a point where the GPR of the earth at time of fault is 1880 volts. There are also several other locations where there are pedestals in the zone-of-influence.

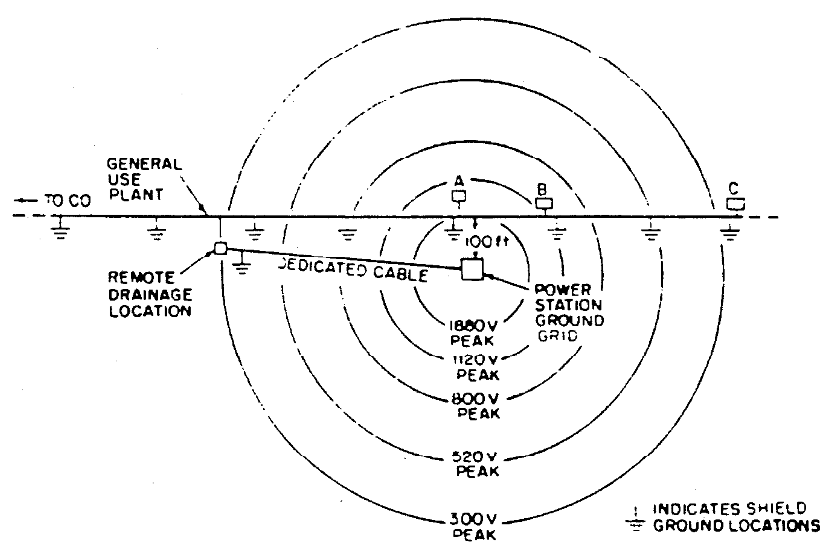

Fig. 5 General Layout of Cable Near Substation

3. SPREADSHEET CALCULATIONS

For the spreadsheet calculation, cable shield resistance and grounding toward the central office as well as the data on the outer end of the cable have also been entered entered. A 22 x 22 matrix, not shown, is set up. The spreadsheet entries and solution are shown in Fig. 6.

	Dist fr CO	GPR	Loop	Loop Cur	Ca Shield
Ped Grnd Ohms	Kft	Volts	Volts	Amperes	Volts
50	**0**	**0**			6.395687
	0.75	**0**	**0**	-8.53	9.427242
Manhole Grnd Ohms	**1.5**	**0**	**0**	-13.24	14.13449
2	**2.25**	**0**	**0**	-20.31	21.35414
	3	**0**	**0**	-30.99	32.3695
CO Grnd Ohms	**3.7**	**0**	**0**	-47.17	48.02059
0.75	**4.4**	**0**	**0**	-71.18	71.6383
	5.1	**300**	**-300**	-107.00	107.14
900 pr 26 ga Cable	**5.2**	**400**	**-100**	-103.14	112.03
Shield Diam - inches	**5.5**	**800**	**-400**	-97.38	125.88
1.8	**5.8**	**1880**	**-1080**	-83.90	137.81
Shield Imp. Ohms/kf	**6**	**1880**	**0**	-49.06	142.46
0.408 + j.242	**6.2**	**1250**	**630**	-14.31	143.82
0.474	**6.55**	**520**	**730**	7.82	142.52
	7	**200**	**320**	15.37	139.24
50 pr 26 ga Cable	**7.15**	**100**	**100**	16.58	138.06
Shield Diam - inches	**7.6**	**0**	**100**	15.82	130.80
0.37	**8.2**	**0**	**0**	13.21	122.72
Shield Imp. Ohms/kf	**9**	**0**	**0**	10.75	113.94
0.978 + j0.278	**9.5**	**0**	**0**	8.47	109.62
1.02	**10**	**0**	**0**	6.28	106.42
	10.5	**0**	**0**	4.15	104.30
	11	**0**	**0**	2.07	103.25

Fig. 6 Spreadsheet Data

The highest current flow during the time of fault is 107 amperes between the 4.4 and 5.1 kft points. The negative sign indicates that current is flowing toward the central office.

The highest voltage to remote earth of the cable shield is 144 volts at the 6.2 kft point. Since the pairs in the cable are grounded at the central office, the maximum cable-to-shield voltage is 144 volts.

The GPR voltage and the resulting cable shield voltage to remote ground is plotted in Figure 7.

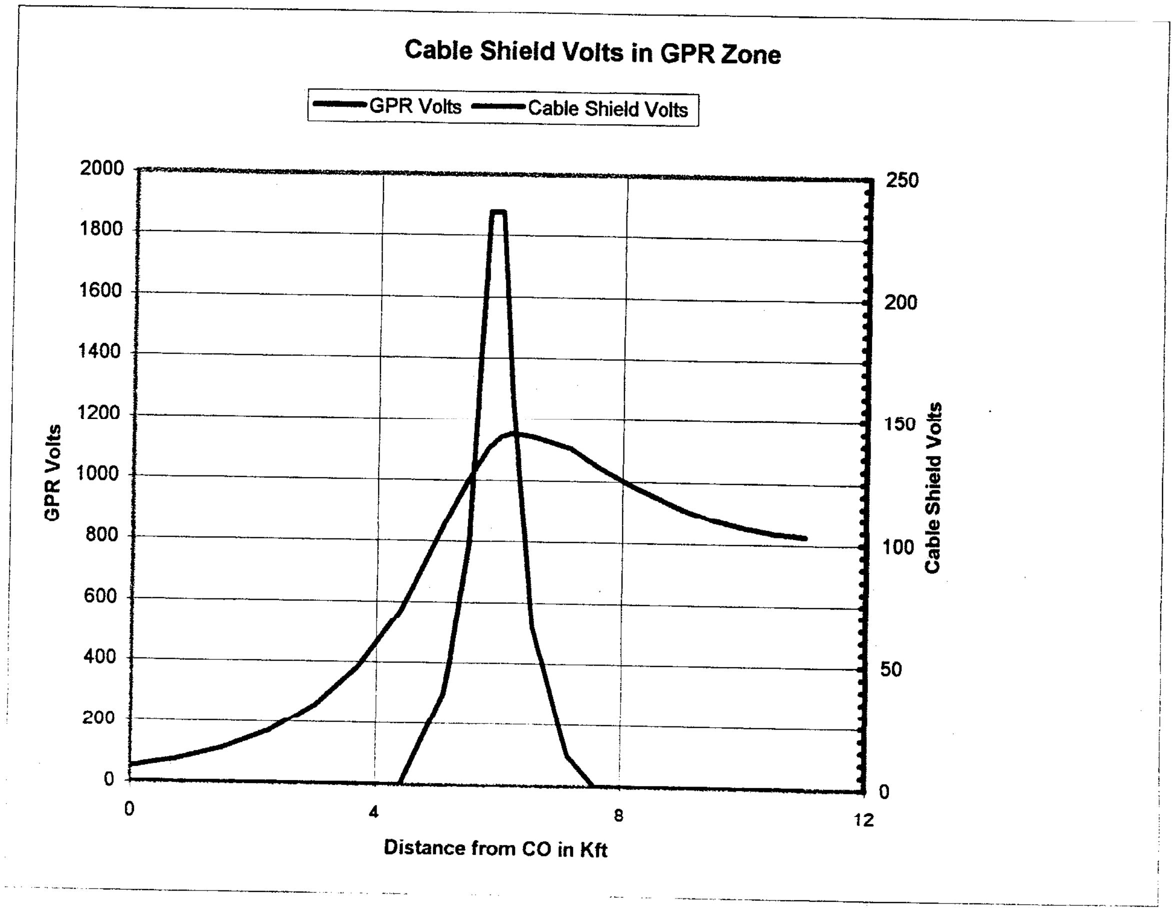

Fig. 7 Plot of Spreadsheet Data

3. CONCLUSIONS

When a telecommunications cable with a continuous metallic shield is grounded in an area where the earth potential will rise during a power line fault, the metallic shield will not assume the same potential as the surrounding soil because of the resistance of the soil surrounding the grounding electrode. This soil resistance also acts to reduce the current flowing on the cable shield. In the example shown in Figure 6, the highest shield-to-pair voltage was 144 volts although the GPR was 1880 volts. The highest flow of current for the duration of the fault was 103 amperes. Other values for GPR, cable size, pedestal grounds, etc. can be entered to calculate cable shield current and voltage to remote ground. Hardware for bonding across shield openings, when properly installed, will carry 1000 amperes rms for 20 seconds. Power line faults that produce significant GPR will be normally cleared in a few cycles.

Cable shield continuity and normal pedestal grounds provide the most safety for craft persons and customer locations served by a general use cable in a power station zone-of-influence. Cable damage near substations is usually not due to raised earth potential, but to direct connections from cable pairs and/or shield to the substation grid by way of a low impedance multi-grounded-neutral conductor. Most cable damage from electrical sources is due to arcing. Full-count protection placed at strategic locations can eliminate the damage to arcing