

DEATH BY GROUNDING

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Donald W. Zipse, P.E.
Life Fellow, IEEE
Electrical Forensics, LLC.
don.zip@ieee.org

PO Box 7052
Wilmington, DE 19803-0052

671 Kadar Drive
West Chester, PA 19382-8123

Abstract – Misunderstandings concerning stray current and equipotential planes are prevalent in North America. Clarification of and differences between equipotentials found in high voltage cable and in concrete encased re-inforcing bar installations in concrete pads and swimming pools are explained. Misunderstanding and false interpretation of the IEEE Standard 80, "Guide for Safety in AC Substation Grounding" has led to flawed conclusions and the false concept of equipotential planes, which are shown to be erroneous and are debunked by tests performed in the field. Also discussed are the dangers associated with bare concentric neutral high voltage cable, the use of can and has contributed to the proliferation of stray current which has resulted in death.

Index Terms – Bare concentric neutral cable, equipotential planes, multi-grounded neutral, stray current, stray voltage.

DEFINITIONS

Bonding (Jumper): A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected. [1] The connection together of two or more electrically conductive parts using an electrical conductor.

EPRI: Electric Power Research Institute. "Created by the nation's electric utilities in 1973, EPRI is one of America's oldest and largest research consortia, with some 700 members and an annual budget of about \$ 500 million. Linked to a global network of technical specialists, EPRI scientists and engineers develop innovative solutions to the world's toughest energy problems while expanding opportunities for a dynamic industry." (Contained in foreword of EPRI documents)

Equipotential: 1. Having equal potential. 2. Physics. Having the same electric potential at every point.

Equipotential Bonding (Swimming pools): Equipotential bonding shall be required to be installed to reduce voltage gradients in pool areas consisting of a 300 mm (12 inch) by 300 mm (12 inch) grid 8 AWG bare solid copper conductors. [1]

"(A) Performance. The equipotential bonding required by this section shall be installed to eliminate voltage gradients in the pool area as prescribed." National Electrical Code (NEC) 2005, Section 680.26

Equipotential lines – Cable, dielectric field: The locus of points having the same potential at a given time. (PE) 81-1983 [2] "In all dielectric cables, irrespective of their voltage ratings, there is a dielectric field present when the conductor is energized. This dielectric field is typically represented by electrostatic flux lines and equipotential lines between the conductor and electric ground". [3]

Equipotential plane: Equipotential means having the same electrical potential throughout: plane means a flat or level surface; together they form a level surface having the same electrical potential throughout.

Equipotential plane as constructed: An area where wire mesh or other conductive elements are embedded in or placed under concrete, bonded to all metal structures and fixed nonelectrical equipment that may become energized, and connected to the electrical grounding system to prevent a difference in voltage from developing within the plane. NEC 2005, Section 547.2.

Zipse' Law: "In order to have and maintain a safe electrical installation: All continuous flowing current shall be contained within an insulated conductor or if a bare conductor, the conductor shall be installed on insulators, insulated from earth, except at one place within the system and only one place can the neutral be connected to earth."

Zipse' Law is the standard for electrical installations in industrial, commercial and residential facilities including utility companies' office buildings. Electrical utility distribution and transmission system should also comply with Zipse' Law.

I. INTRODUCTION

The Petroleum and Chemical Industry Committee (PCIC) of the Industry Applications Society (IAS) of IEEE provides a forum for the exchange of electrical applications technology. Safety has always been a primary concern of the PCIC conference. With the formation of the Electrical Safety Session and the Electrical Safety Workshop in 1991 there has been an expansion and concentration of information and knowledge influencing electrical safety.

Misunderstanding of grounding principles influences electrical safety. The PCIC paper presented in 2001 titled,

¹Excerpted from *American Heritage Talking Dictionary*.
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“Earthing – Grounding Methods: A Primer” [4] revealed the misunderstandings, the errors and the remedy to rectify the errors. This paper is a continuation of that theme. However, the stakes have been raised. The results of the following misunderstandings can be death. Death can result from improper grounding and/or lack of understanding of the function of “grounding” and how bonding performs.

The paper will discuss false concepts and misunderstandings concerning stray man-made, generated current. Current from static as can be generated from shuffling your feet over carpet in low humidity is not included in this paper. It may appear that the subject of this paper is of little concern to the reader. However, unless you generate your own electric power, have no connection with the utility's common neutral conductor, the telephone system and the cable company and are on a remote island, you can be affected by stray current. As has been shown in the paper titled, “Equipotential Planes: A Figment of the Imagination” [5] stray current enters a premise by a direct electrical connection of the utility's distribution system's pole, pad or underground transformer's non-standard industrial electrical connection of the primary neutral to the secondary neutral. In addition to the direct electrical connection from the primary neutral to the service entrance equipment grounding conductor there is the stray current that is also flowing across the earth from the numerous electrical connections of the utilities' return neutral distribution conductor to earth. Thus, there are two ways that stray current enters the earth, directly connected and through the multitude of down grounds on the return neutral conductor. See Fig 1 and 2 at the end of the paper.

Years ago and unfortunately even today, there are persons who think that any object that is grounded or connected to earth can be safely touched. This misconception has no doubt contributed to many electrical accidents. Likewise, the misconception that voltage kills is accepted by many in today's world.



Illus. 1 Girl holding onto 400,000 volt Van de Graaff generator.

Misconception: It is thought by some that it is voltage that kills. The picture of the young girl holding onto a Van de Graaff generator refutes the false concept that voltage kills.

II. IS IT STRAY VOLTAGE OR STRAY CURRENT?

“Is it stray voltage or stray current” is covered in great detail in the paper, “The Hazardous Multigrounded Neutral Distribution System and Dangerous Stray Currents”. [6] Voltage does not stray since voltage is a function of the current times the resistance, Ohms Law. Overlooked was this simple fact that it was the current that flowed uncontrolled through the earth. It is a fact that with the multigrounded neutral distribution system the stray current CANNOT be limited in magnitude or where in the earth the stray current flow can be directed. Therefore, when the word “uncontrolled” is used it is applied to both the magnitude and location of flow of the current in the earth.

With the advent of ever-increasing electrical load, the neutral distribution current flows through the earth in ever-increasing amounts. It is a fact that the Electric Power Research Institute (EPRI) states that 60 percent of the neutral return current from a multigrounded neutral electrical distribution system returns to the source substation through and/or over the earth.[7] Testing has revealed higher percentage. In one case up to 81 percent of the primary distribution current was returning uncontrolled through the earth to the source substation. The above was entered into court records.

As a side comment Edison did not call his type of electrical distribution system Direct Voltage, but Direct Current. Likewise, Nikola Tesla and George Westinghouse called their type of electrical system Alternating Current, not Alternating Voltage.

Anyone placing two leads of a voltmeter into the earth is likely to measure a voltage. Before 1950, it is opined new employees of utility companies were given relative low cost voltmeters instead of expensive ammeters enabling them to make voltage measurement anywhere in the earth instead of current measurements. The author was 30 years old with 14 years of electrical experience before obtaining an ammeter because of the high costs.

In the early 1980s, four agriculture professors misinterpreted IEEE Standard 80, Guide for Safety in AC Substation Grounding, wrote three papers expounding equipotential planes to reduce the voltage gradient in dairies and used the term “stray voltage”. The combination of above events contributed to the adoption of the incorrect term, “stray voltage”. In addition, based on their three papers expounding the false concept of equipotential planes the NEC Making Panels were duped into adopting the concept in dairies and swimming pools.

Professor Dalziel in 1946 states, “Perhaps the most serious misconception concerns the effects of voltage versus the effects of current. Current and *not* voltage is the proper criterion of shock intensity.”[8] It is a shame the U.S. Department of Agriculture, the American Society of Agriculture Engineers and others who coined and use the term “stray voltage” failed to do adequate research on the subject.

Placing two leads of a voltmeter into the earth constitute two fixed points, non-movable. It is the primary neutral distribution current that flows over and through the earth on its way back to the source, the distribution substation that is straying. Thus, the correct term is “stray current”.

III. BONDING OR GROUNDING GRIDS

The National Electrical Code Handbook [9] states that there are three basic reasons for grounding:

(1) To limit the voltages caused by lightning or by accidental contact of the supply conductors with conductors of higher voltage

(2) To stabilize the voltage under normal operating conditions (which maintains the voltage at one level relative to ground, so that any equipment connected to the system will be subject only to that potential difference)

(3) To facilitate the operation of overcurrent devices, such as fuses, circuit breakers, or relays, under ground-fault conditions [9]

Missing from the above list is the greater safety for personnel.

It is opined that rarely if ever any consideration has been given to the concept of an electric current flowing continuously over a bonding conductor or equipment grounding conductors. If considered, it is only for the momentary condition of an electrical phase-to-neutral fault to provide a path back to the source to open the protective device. The duration time of the fault condition is momentary and NOT continuous.

It must be noted that the equipment grounding conductor and bonding conductors are NOT supposed to carry continuously flowing current. Since they are NOT supposed to carry continuous flowing current, called stray current, that stray current can be classified as "objectionable". Both the National Electrical Safety Code and the NEC contain information about "objectionable current" and what steps are to be taken to minimize it. Those steps are rarely recognized or applied by the utilities or electrical engineers.

Stray current flowing uncontrolled over the earth means that the amount of stray current cannot be controlled nor can the location where the stray current flows be controlled.

Equipment grounding conductors and bonding conductors have resistance. When there is a continuous flow of stray current through a resistance, Ohm's Law must be applied. However, the equipment grounding and bonding conductors are connected to earth. They are grounded, earthed. How can bonding and grounding conductors have a voltage difference or a voltage gradient when they are connected to earth?

Misconception: When a conductor is connected to earth, grounded, that connection to earth extends the ground, earth, connection and thus there is no voltage between the grounded conductor and earth. This is correct if and only if there is no current flowing over that conductor.

A simple example would be back in the 1920s before Occupational Safety & Health Administration (OSHA) and before electrical safety programs linemen would work the neutral barehanded since the neutral was connected to earth back at the substation. However, if for example a 13.2 kV distribution circuit extending 32.2 km (20 miles) carrying 20 amperes on the neutral over an uncoated 1/0 copper conductor with a dc resistance of 0.1 ohms per 304.8 m (1,000 feet), the voltage drop over the 32.2 km would be 211 volts.

Should the lineman out at the 32.2 km location touch both the neutral and a conductor connected to earth at that location, he would receive 211 volts. Since voltage does NOT kill, but it is the current, should his hand-to-hand resistance be

5,000 ohms he could have received 42 mA flowing through his chest, which is sufficient to set his heart into fibrillation that could result in death. If he had suffered fresh cuts on both hands, his hand-to-hand resistance could be only 500 ohms and the current through his chest cavity would be 422 mA. In this example, the primary neutral distribution return current is a continuously flowing current.

Today the solution that has been adopted due to OSHA and various electrical safety programs is a lineman cannot work any energized conductor barehanded. Unfortunately, the solution adopted before OSHA was to ground the distribution neutral four (4) times per 1.6 km (1 mile). With the neutral connected to the earth approximately every 0.4 km the expected voltage drop in the middle of the distance would be less than 30 to 35 volts, thus affording a safe working condition for linemen working the neutral barehanded.

The outcome of this lack of understanding of the consequences of earthing the primary distribution neutral was the parallel connection of the neutral to earth allowing neutral current to enter the earth every 0.4 km and flow uncontrolled through the earth on its way back to the distribution substation in parallel with the neutral. This is the reason that EPRI states that 60 percent of the primary current is expected to flow back over the earth and the reason that measurements of over 80 percent of the phase current have been recorded flowing over the earth on the return path back to the source substation.

IV. EQUIPOTENTIAL

The word "equipotential" is applied to cable, swimming pools, dairy and swine farms and other similar installations.

Equipotential Lines as Applied to Cable

An energized non-shielded conductor produces electrostatic flux lines. See Fig. 3. In Fig. 4, equipotential lines from a non-shielded cable are shown. The flux lines and the equipotential lines are distorted.

Data has been collected and it has been determined that magnetic fields are not a factor in stray current in dairy or human cases. This paper is not concerned with magnetic fields, as they are not relevant to the discussion.

In shielded dielectric cable, the lines are contained within the insulation and are concentric and parallel with respect to each other. In addition, all the voltage difference between the conductor and ground is also contained within the cable as is shown in Figs. 5 and 6.

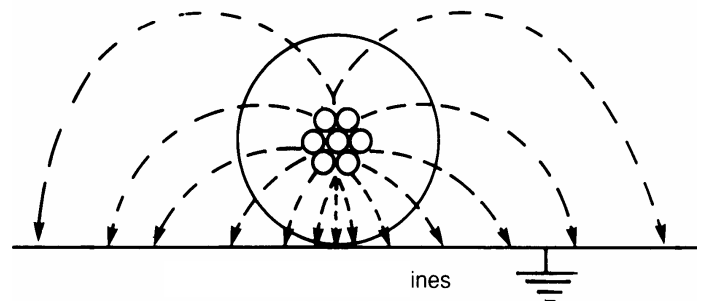


Fig. 3. Electrostatic flux lines from a non-shielded conductor [3]

Equipotential Planes

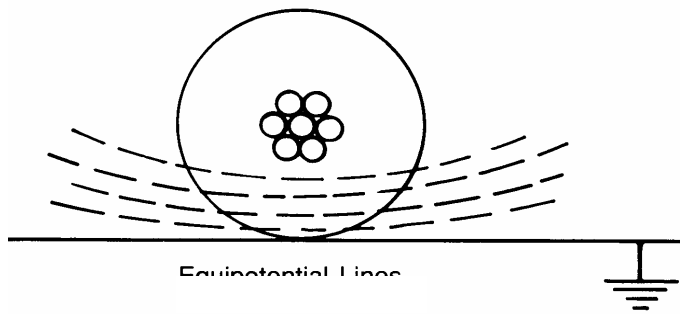


Fig. 4. Equipotential lines form a non-shielded conductor [3]

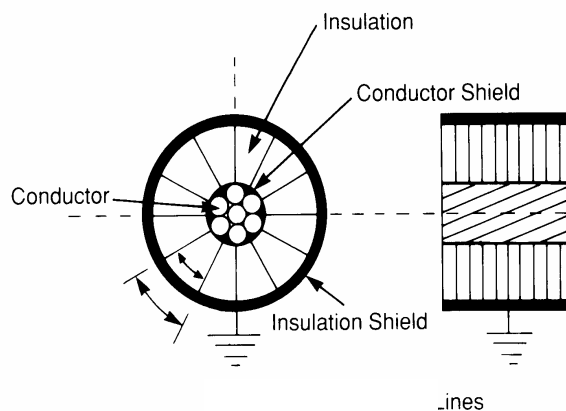


Fig. 5. Electrostatic flux lines within dielectric shielded cable [3]

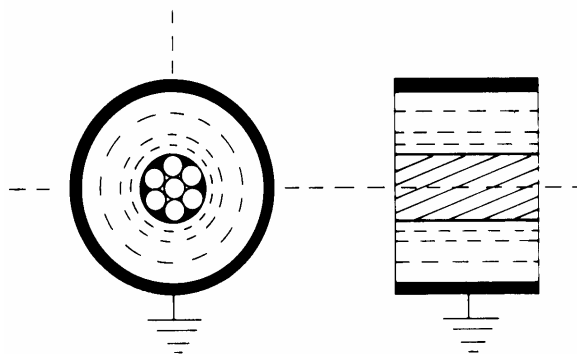


Fig. 6. Equipotential lines within dielectric shielded cable [3]

The major point to retain is the fact that the equipotential lines have a voltage gradient associated with them and the voltage gradient is contained within the insulation.

Misconception: Equipotential planes eliminate voltage gradients and/or prevent a difference in voltage from developing within the plane. In the above example let us assume the copper conductor was extremely malleable, as malleable as gold. If we flatten the round copper conductor into a flat plane would not the very same voltage drop that occurred in the round conductor, occur across the flatten conductor? If the above example of a distribution line voltage drop and the barehanded lineman has not shown the inconsistencies and fallacies of equipotential planes then an example from the right-hand side of the decimal point may.

The foundation for the understanding of the fallacy of equipotential planes for the author began with a vivid description of problems in constructing a solid-state integrated circuit. While leaning against a wall in the late 1960s, waiting to board a plane in San Francisco, a casual conversation with an electrical engineer working for a chip manufacturer took place. He related the problem he had with where to place the leads of components such as resistors on a copper substrate the size of your fingernail. If the leads were placed at opposite corners on this very small piece of copper plate, the current flowing across the copper ground plane would produce a voltage drop across the grounded surface that would interfere with other components.

A grounded copper surface the size of your fingernail had serious problems with current flow across the surface interfering with other components due to a voltage gradient. What would a larger surface such as a concrete pad containing conductive re-bar, or a swimming pool do to a person immersed in water lacking the normal skin resistance to the flow of electricity?

At what level of magnitude of stray current flowing across a concrete pad in a chemical or petroleum facility will the stray current cause interference with sensitive electronic controls or instrumentation? Should workers in an oil field be concerned when multigrounded neutral distribution systems are used in the area? If persons taking showers are being subjected to electric shocks in their homes how soon will the same showers in industrial facilities start shocking employees?

1) *Equipotential Planes and The National Electrical Code:* The 2005 Edition of the National Fire Protection Association's National Electrical Code contains the following requirements for agriculture buildings:

Section 547.2 Definitions.

"Equipotential plane. An area where wire mesh or other conductive elements are embedded in or placed under concrete, bonded to all metal structures and fixed nonelectrical equipment that may become energized, and connected to the electrical grounding system to prevent a difference in voltage from developing within the plane."

The requirements for swimming pools are:

Section 680.26 Equipotential Bonding.

"(A) Performance. The equipotential bonding required by this section shall be installed to eliminate voltage gradients in the pool area as prescribed."

The key words for agriculture buildings are, "to prevent a difference in voltage from developing within the plane" and in the case of swimming pools, "equipotential bonding required

by this section shall be installed to eliminate voltage gradients in the pool area".
As will be shown, one cannot prevent voltage gradients in an equipotential plane.

2) *IEEE Standard 80, Substation Grounding*: It is opined that Robert J. Gustafson, et al and the NEC Making Panels did not take into consideration the purpose of the IEEE Standard 80, "Guide for Safety in AC Substation Grounding".

IEEE Standard 80 states:

1.2 Purpose

"The intent of this guide is to provide guidance and information pertinent to safe grounding practices in ac substation design.

"The specific proposes of this guide are to

"Establish, as a basis for design, the **safe limits of potential differences** that can exist in a substation **under fault conditions** (Author's emphases) between points that can be contacted by the human body.

"Review substation-grounding practices with special reference to safety, and develop criteria for a safe design.

"Provide a procedure for the design of practical grounding systems, based on these criteria.

"Develop analytical methods as an aid in the understanding and solution of typical gradient problems."

It is a fact and is very clear that Clause 1.2 a) states that IEEE Standard 80 is under **fault conditions**. Stray current exists under normal continuous flow of neutral distribution current, under continuous utility operating conditions, not fault conditions.

Professor Robert J. Gustafson wrote, "Gradient control is used by the electrical industry to minimize the risk of hazardous step (foot-to-foot) and touch (hand-to-foot) potentials **under fault conditions** (emphases by author) at substations and around electrical equipment. In addition to protecting people, animals, and equipment **under fault or lightning conditions**, proper equipotential systems in livestock facilities can solve stray voltage/current problems." [10]

	<i>Std. 80</i>	<i>Plane</i>
Object	Protection Step-Touch	No Voltage Gradient
Current Condition	Fault	Continuous Flow
Available Amperes	$> 10^{-3}$	$> 10^{-3}$
Voltage	$< 35\text{ V}$	$> 0.1\text{ V}$

TABLE 1 Comparison of IEEE Standard 80 and Equipotential Planes

It is clearly evident that the adoption of equipotential planes into the NEC Articles 680 and 547 is an enormous mis-

application by the NEC Making Panels resulting from misunderstanding of an electrical principle.

It is opined that the equipotential plane is no more than an earth electrode, which lacks any ability to maintain or to have zero voltage gradient across it when any amount of electrical current flows over, across or through the equipotential plane. As an electrode-earthing element, the equipotential plane has the potential for uncontrolled stray current from the multigrounded neutral electrical distribution system to flow across the equipotential plane generating a dangerous and hazardous voltage to drive the stray current into and through humans and cows and pigs with devastating results.

3) *Verification of Voltage Gradient across Equipotential Planes through Field Testing*: Mr. Lawrence C. Neubauer devised a test to show that when an equipotential plane had a stray current flowing across it, that there would be current flowing through a cow. A bucket with water was placed in the center of an equipotential plane. The bottom of the bucket had an iron plate attached to an iron conductor. The iron conductor ran to an ammeter and from the ammeter, another iron conductor ran to a contact with the equipotential plane under the bucket.

When a cow drank from the bucket, a current ran up the legs of the cow and through the body to the muzzle, mouth, and into the water. From the water, the current was picked up by the iron plate and through the ammeter and back to the equipotential plane. The ammeter recorded the current flowing through the cow from the hoofs, feet in contact with the equipotential plane and back to the equipotential plane at a location at the front of the cow, five to six feet away from the hoofs.

If an equipotential plane prevented a voltage from developing within it then there would be no potential driving the current through the cow. Voltage could have been measured; however, in a trial one must supply the amount of current that is harming the cow, not the voltage. In addition, the defense will demand that the current through the cow be measured. It must be through the cow to be valid. For that reason, we do not measure voltage across the cow.

Over the past couple of years, the resistance of the cows has been measured in the field as verses the sterile conditions of the university laboratories. The findings have shown that the so-called standard cow resistance of 500 ohms is actually doubled that found in the field of 200 ohms average for a cow. Previously before measuring the current directly through the cow an imaginary cow consisting of a voltage reading across a resistance of 470 ohms was used. However, there is a difference in the resistance between cows and measuring the actual current flowing through the cow eliminates any questions as the actual resistance of a cow. Four-hundred and seventy ohms is the nearest standard resistor value available.

Data of the actual current through cows has been taken since December 2004 when the bucket test was first conceived. A sample of the data collected was presented at the 2006 Industrial & Commercial Power Systems technical conference's paper titled, "Equipotential Planes: A Figment of the Imagination" [5] Current through the cow has been presented in testimony at depositions and trials since 2004.

The iron conductor and iron plate were used to eliminate any galvanic action between the iron re-bar and a copper

conductor. We have not tried to measure the current flowing through a human . . . yet.

V. DEATH BY GROUNDING

The following are not isolated incidents. Each year more and more reports of electrical shocks from stray current are being documented. Cows have four feet in contact with the earth and appear to be much more sensitive to and succumbing to the adverse reactions of stray current and the resulting electric shocks than humans are. It is only a matter of time until these shocking incidents increase in quantity. The general public will then demand to know why and will become informed of the hazardous and dangerous distribution practices used by utility companies. Considering the fact that some, if not many utilities, are decreasing the maintenance activities [11] and the electrical load is ever increasing, the level of stray current incidents will also increase along with the severity of the shocks.

A. Swimming Pool Electric Shock

Excluding utility workers, electrical engineers in the world expect all conductors to be insulated and all current that flows from a transformer will return to that transformer over conductors, not the earth. Nine years ago inhabitants of an apartment complex complained of receiving electrical shocks while using the swimming pool. The swimming pool was in the center of the apartment complex. The electric shocks occurred when the temperature was above 95 degrees for several days and after 5 p.m. when the inhabitants returned from work and turned on the air conditioning, lights and started their electric appliances. Stray current is dependent upon electrical load.

In the late morning when the electrical load was low, a lineman was asked to read the primary current flowing to two underground transformers feeding four of the 10 buildings. The lineman placed his ammeter around the phase conductor of the termination of the bare concentric neutral conductor at the riser pole and called, "Forty-two amperes." "What is the current on the bare concentric neutral conductors?" "Oh, we do not bother to read the neutral." "Humor me and read the neutral." Twenty-two amperes was the reply. "Where did the other 20 amperes go? "Oh, that is normal." [12]

It might be normal for the utilities in North America, but not for electrical engineers working in other endeavors. Nor is it normal outside of North America to have 48 percent or as high as 80 percent of the phase current flowing uncontrolled over the earth on its way back to the substation.

The electric chair keeps the current below 5 amperes to keep from burning the human body. Twenty amperes or 48 percent of the phase current flowing continuously, uncontrolled, returning over the earth, was not only outrageous, but also dangerous and hazardous. This unsafe, life-threatening, flow of stray current over the earth happens only in North America. Stray current flowing uncontrolled over the earth is not normal for the rest of the world.

B. Swimming Pool Death

At a campground with a swimming pool, it was reported about 9:00 am that persons in the pool were being bitten by

(imaginary) fish. This is a normal reaction to electric shock, especially if the person has open cuts or fresh abrasions to the skin. One young boy reported that when exiting from the pool his muscles froze and he could not move. He was frozen in place. He was able to fall back into the water. The management turned off all the electric power to the swimming pool.

Turning off all the electric power means that the energized conductors, the phase conductors, were disconnected. It does not mean that all the conductors are disconnected since the neutral and the equipment-grounding conductor are still connected and are still supplying stray current to the pool. Without any electric power the circulating pumps were not working. The pool became cloudy and by noon, the pool visibility was less than a meter (3 feet).

About 11:00 a.m., a 10-year-old boy was last seen. At noon, his parents arrived to take him home after spending the night with friends. However, he could not be found. Approximately 1:30 p.m. a young girl stepped on the boy's body at the bottom of the swimming pool.

It is opined that the young boy suffered an electrical shock that froze his muscles resulting his being drowned. The neutral and the equipment grounding conductor were still connected to the swimming pool affording a direct electrical connection from the primary neutral directly into the pool for the continuous flow of uncontrolled stray current on its way back to the original substation. The so-called equipotential plane with its excellent earth connection from the concrete encased re-bar in intimate contact with the earth is a low resistance connection to the earth. This low resistance electrical connection to the earth affords an excellent path for the flow of stray current on its way back to the substation.

The electrical engineer investigating the accident confirmed that the pool was wired according to the NEC. Unfortunately, the electrical engineer who was experienced with and knowledgeable about the NEC knew little about stray current.

C. Bare Concentric Neutral Cable

Of the several instances of bare concentric neutral cable involved in shocking circumstance one cow and one human will be described. Bare concentric neutral cable, also known as underground residential distribution (URD) cable came on the market approximately in the late 1950s – early 1960s. It was used predominately by the utilities as a cost saving method for distribution level voltages. See Fig. 7. The cost savings was in the lack of an outer jacket. The bare concentric neutral consisted of annealed coated copper concentric wires of a range of 10 - # 14 to 20 - # 10 AWG, that were uniformly spaced around the insulation screen and in sufficient number to supply full or 1/3 conductivity of the power phase conductor rating.

In the late 1950s it was commonplace for the utilities to install only a return neutral of 1/3 ampacity of the phase conductor. The utilities relied upon the earth to carry the balance of the neutral return current back to the originating substation since the bare copper neutral was in intimate contact with the earth. This contact allowed neutral current to leave the under sized copper neutral conductor and enter the earth resulting in stray current flowing uncontrolled over the earth inflicting harm on the unsuspecting public.

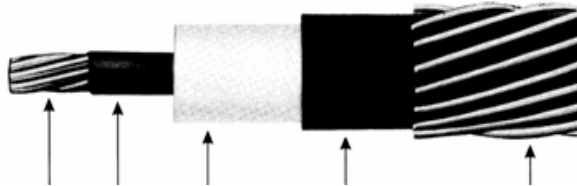


Fig. 7. Bare concentric neutral cable.

Misconception: The concept and adoption of the bare concentric neutral being in intimate contact with the earth provided improved earthing/grounding of the electrical distribution system along with a less costly installation method and thus was a benefit to the public.

It is opined that the concept, design, manufacturing and installation of the bare concentric neutral cable will be considered in the future as one of the most significant misjudgment, miscalculation and momentous mistake in utility applications.

It is opined that all bare concentric neutral cables should be removed from service immediately and replaced. Bare concentric neutral cable, even if installed in conduit or duct should also be removed from service because underground the conduit or duct can fill with water affording a conductive path for neutral current to return back to the substation using the earth for the path.

D. Dairy Cows Death Due to Bare Concentric Neutral

A bare concentric neutral distribution cable was installed across the property of a dairy to supply a transformer located next to the milking parlor. The dairy was expanded and additional free stalls constructed directly over the unknown bare concentric neutral cable. The stray current shocked the cows when they tried to drink and thus an intake of 151 L (40 gallons) of water per day was unattainable. Intake of water is critical for the production of the expected normal output of 36 to 41 kg (80 – 90 pounds) of milk per day. Not only was milk production reduced, but also the cows were dying.

Once it was disclosed that the dairy had built directly over the bare concentric neutral cable, the solution was to supply the dairy by an aerial distribution system and abandon the direct buried bare concentric cable.

E. Death by (Grounded) Bare Concentric Neutral Cable

One evening at a home in a large development, a birthday party for a teenager was going full tilt. It was supervised by the birthday boy's parents. A group was in a hot tub. Three boys and a girl, jumped out, raced down to the dock and jumped into the lake. Immediately their bodies were electrically shocked and their muscles froze rendering them helpless. One boy managed to stay afloat. He reported that he could hear and see, but could not move his arms or legs.

The father of the birthday boy jumped into the lake and pulled the floating boy out. The boy yelled that three more were in the lake. The father dove down and pulled the other three out. Fortunately, there was a person at the party that was trained in CPR and CPR was applied to the victims.

The police officer, looking over the edge of the dock, observed a metallic chain hanging in the water. It was glowing and dead fish were floating around the chain. In addition, there was a varmint, raccoon or opossum floating nearby.

The local utility lineman responded. He reported that he tried to separate the conductors supplying the dock's boat elevator, which was not running and light(s) in order to take current readings of the conductors. When he could not part the conductor sufficiently enough to get his ammeter around any conductors, he placed his ammeter around all the conductors and the flex. He reported 10 amperes.

Just to make it perfectly clear, the 115-volt phase current from the house was flowing down to the dock for light(s) would generate an electric field in the opposite direct to the neutral return current. Thus, there would be no reading on the ammeter since all conductors were enclosed within the jaws of the ammeter. However, the lineman recorded 10 amperes flowing over the circuit to the dock.

The utility had wired the development using direct buried bare concentric neutral cable. One section of the distribution circuit was laid across the lake. The bare concentric conductors had been tested a few years back and found that only a few neutral conductors were still present in the section under the water, the rest having deteriorated. In order to insure adequate neutral connections additional neutral conductors had been installed and connected to both ends of the section of cable under the lake.

The floater survived. A boy and girl suffered brain damage due to being without oxygen for too long a period. The boy's death certificate read, "Electrical shock contributing to drowning".

VI. SOLUTIONS

There are two sources of stray current. 1) The direct wired electrical connection between the primary neutral and the secondary neutral. 2) The multiple electrical connections between the return neutral conductor and the multiple down grounds are the other source. Success has been achieved in eliminating danger and hazardous stray current from both sources flowing through a dairy in Wisconsin. [14] Some of the methods are:

A Remove the Multigrounded Neutral Distribution System

The root cause of stray current is the use of the multigrounded neutral distribution system (MGND). Elimination of the MGND system eliminates both the direct electrical connection of the primary neutral into the facility and the stray current flowing over the earth from the multiple connection of the neutral' down grounds to earth.

An estimate for correcting the MGND system in rural Wisconsin over 8.5 miles ranged between \$8,000.00 and \$ 10,000.00 per mile. In another case, the utility blew \$ 250,000.00 installing a larger neutral conductor in a development thinking that a larger neutral would solve the problem. The author was quoted as stating that an over sized neutral would not be a solution to stray current. He was proven correct the next summer when the stray current problem remained and The Georgia Institute of Technology's

NEETRAC also stated that enlarging the neutral would not be a solution. The \$ 250,000.00 would have eliminated the multigrounded neutral distribution system. Approximately eight years ago, the distribution system was a 3-phase delta with primary phase-to-phase transformers. Such a distribution system does not have any neutral, thus there is no return neutral current flowing over the earth nor is there any primary neutral to secondary neutral electrical connection allowing stray current to flow directly into one's home.

B. Neutral Blocker Installed by Utility

In order to prevent the continuous flow of stray current from the primary neutral conductor to the secondary neutral conductor, which is directly connected to a home or dairy's equipment grounding conductor, a few utilities will install a neutral blocker. A neutral blocker is similar to a lightning arrester. When placed between the solid electrical connection of the primary neutral and the secondary neutral the stray current flow is prevented from flowing into the premises. However, the neutral blocker will not stop the stray current flowing over the earth. This is the first method requested of the utility. However, only some of the utilities will comply.

C. Transformer to Function to Isolate the Primary Neutral from the Secondary Neutral

When the utility refuses to install a neutral blocker, a customer owned transformer could be installed. The transformer is like what industrial and commercial electrical engineers install every day without any electrical connection between the primary and the secondary neutral.

The neutral/ground conductor from the transformer must be connected only to the customer owned transformer. A new electrical grounding system must be started on the secondary side of the customer owned transformer. The grounding electrode must be located at least 22 feet away from the customer owned transformer and in the opposite direction from the distribution line. The object is to have a customer grounding system that is NOT connected in any way to the utility multigrounded neutral distribution system.

D. Re-arrange the Distribution System to Eliminate Stray Current from Flowing Over the Earth

If the facility suffering from stray current is physically between the substation and the source of the stray current flowing over the earth from the multiple neutral to earth connection, it may be possible to feed the portion beyond the facility from another distribution circuit. The current that was flowing through the facility would then be flowing in the opposite direction, away from the facility.

E. Action that the Reader Can Take

Since the National Electrical Code Making Panel responsible for swimming pools has adopted equipotential planes about 1990 and it has been shown that equipotential planes are a figment of the imagination, the reader is encouraged to submit a proposal to eliminate Section 680.26 Equipotential Bonding.

In addition, your support by submitting a proposal to eliminate equipotential planes in Article 547, Agriculture Buildings, Section 547.10 Equipotential Planes and Bonding of Equipotential Planes would be greatly appreciated. The form to make a proposal to change the NEC for the 2011 edition can be found at: http://www.nfpa.org/assets/files/PDF/CodesStandards/2011N_ECProposalform.doc Since the NEC Making Panels frown on identical submittals, suggested wording will not be proposed, but you are urged to develop your own proposal wording. The submittal deadline is 5 p.m. EST, Friday, November 7, 2008. Proposals received after 5 p.m. are returned to the submitter.

A proposal to eliminate the National Electrical Safety Code, Rule 097, D, 2 Multi-grounded systems, would go a long way toward a safer electrical distribution system, free from the continuous flow of dangerous and hazardous stray current. The schedule for the 2012 NESC cycle can be found at <http://standards.ieee.org/faqs/NESCFAQ.html#q4>. The reader is also urged to submit comments on the NESC proposals in c/o the IEEE Standards Office, 445 Hoes Lane, Piscataway, NJ 08854-4141.

VII. CONCLUSIONS

The correct term is stray current, NOT stray voltage. Voltage does NOT kill, as it is the current that can result in death.

With the decrease in maintenance of electrical distribution lines, the growth in electrical usage and the resulting increase electrical load on the primary electrical distribution circuits, an escalation in the dangerous and hazardous flow of stray current over the earth and into our homes and facilities will occur.

If a continuous current is flowing across a bonding and/or equipment grounding conductor then there will be a voltage difference. The voltage difference is a function of Ohm's Law. The use of bonding and grounding conductors can give a false sense of safety. Consideration must be given to analyzing what effect continuous flowing current over bonding and grounding conductors will have on humans and animals.

Most electrical engineers in the world consider the electrical utility systems' primary neutral being connected directly to the secondary neutral of a transformer and thus directly into a home, a non-standard electrical connection.

With the amount of stray current flowing uncontrolled over the earth and flowing over other electrically conductive paths, it is only a matter of time until electrical injuries increase to an unacceptable level.

When the public becomes educated and made aware of the dangers and hazards associated with uncontrolled flow of stray current, it is hoped that a public clamor of protest will arise and action taken to rectified the situation. This corrective action should start with the National Electrical Code Making Panels correcting their mistakes concerning equipotential planes in swimming pools and dairies.

VIII. ACKNOWLEDGMENT

Mr. Lawrence C. Neubauer is continuously seeking new ways to measure the amount of stray neutral distribution

current flowing through cows. He devised the concept of the testing cows drinking out of an instrumented plastic bucket on an equipotential plane and eating out of a plastic container that revealed the fallacy of the equipotential plane concept. Mr. Neubauer has been invaluable to the author.

Mr. Neubauer has eliminated the excruciating wait for a cow to drink from a bucket of water. He now locks the cow's head in the stanchions and drives down the aisle stopping to place a nose ring in the muzzle, recording the stray current reading and proceeding onto the next cow. This procedure eliminated any delay in having to wait for the cow to decide to drink, knowing that she will be shocked. Mr. Neubauer is an outstanding Master Electrician with exceptional practical knowledge.

IX. REFERENCES

[1] NFPA Standard 70, National Electric Code – 2008 Edition.

[2] The IEEE Standard Dictionary of Electrical and Electronic Terms, IEEE Std. 100-1996.

[3] Power Cables Manual, Southwire Company, First Edition, 1991.

[4] D. W. Zipse, "Earthing – Grounding Methods: A Primer", PCIC *Conference Record*, PCIC-01-02, Sept. 2001.

[5] D. W. Zipse, "Equipotential planes: A Figment of the Imagination", I&CPS *Conference Record*, ICPS 06- , May 2006

[6] D. W. Zipse, "The Hazardous Multigrounded Neutral Distribution System and Dangerous Stray Currents", IEEE – IAS – PCIC *Conference Record*, PCIC-03-03, Sept. 2003.

[7] EPRI, "Identifying, Diagnosing, and Resolving Residential Shocking Incidents", Final Report, page I - 5 Sept. 1999, TR-113566

[8] Charles F. Dalziel, "Dangerous Electric Currents", AIEE Transactions, August – September 1946, Vol. 65, pp. 579 – 585

[9] NEC Handbook, 2005 Edition, NFPA, Quincy, MA

[10] "Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems", Agricultural Research Service, Beltsville, MD, Dec. 1991 obtain from U.S. Department of Commerce, National Technical Information Service.

Also

"Effects of Electrical Voltage/Current on Farms Animals", Agricultural Report AH-696, available from U.S. Department of Commerce, National Technical Information Service, Springfield, VA 22161

[11] "Operating to Failure", Article in St Louis Post-Dispatch, St Louis, MO, Sunday, July 22, 2007

[12] D. W. Zipse, "Are the National Electrical Code and the National Electrical Safety Code Hazardous To Your Health? (Subtitled, "The Shocking Swimming Pool")", I&CPS *Conference Record*, I&CPS-99, May 1999.

[13] Russ Allen, "Electrocution of America: Is Your Utility Company Out to Kill You?", Glenmore Books (December 2007), WI, ISBN-10: 0977968502, ISBN-13: 978-0977968503.

X. APPENDIX

Stray Current Detection and Measurement for Residential or Commercial Facility

Aerial Service: Using an ammeter with a preferred resolution of milliamperes, place the clamp-on ammeter around all service conductors at the same time. The reading will be the amount of stray current flowing within the facility. The reading is accurate regardless of whether there is an electrical load or not.

Pad Mounted or Underground Transformer Service:

1) Using the required Personal Protective Equipment (PPE), 2) turn off the main service entrance protective device, circuit breaker or fuse and 3) remove the panel cover.

4) Carefully, place the clamp-on ammeter around the incoming, line side neutral and read the instrument. The reading will be the amount of stray current flowing on the neutral.

Verifying No Neutral to Ground Faults Within the Facility: 1) Using the required Personal Protective Equipment (PPE), 2) turn off the main service entrance protective device, circuit breaker or fuse and 3) remove the panel cover.

4) Turn off all the branch circuit breakers. 5) Carefully remove each branch neutral conductor one at a time from the neutral bus bar. 6) Using an ohmmeter check the neutral conductor that has been removed to ground, frame of the panel being assured that the frame is grounded. If the reading is infinity there is no neutral to ground fault within that branch circuit. If there is a resistance value then there is a neutral to ground fault that can be contributing stray current to the facility. 7) Re-install the branch neutral conductor onto the neutral bus bar. 8) Repeat for each branch neutral conductor by repeating item 5 until all neutral branch conductor have been measured.

XI. VITA

Donald W. Zipse (S'58-M'62-SM'89-F'94-LF'97) graduated from the Williamson Free School of Mechanical Trades with honors where he gained practical experience in electrical construction and in power plant operation. He received his electrical engineering degree from the University of Delaware and went to work for Cutler-Hammer as an area sales engineer. He spent 16 years with ICI America, Inc in their Central Engineering Department as a company wide electrical specialist.

For the next 14 years, he was with the FMC Corporation in their Engineering Service organization, functioning as an

Electrical Engineering Consultant, responsible for providing electrical design of new facilities and consulting service to the total worldwide corporation, both chemical and mechanical groups.

He is a registered Professional Engineer. He represents the IEEE on the National Electrical Code Making Panel #14, Hazardous Locations. He has served on the Lightning Standard NFPA 780 and is a member of the International Association of Electrical Inspectors. He serves on the National Electrical Safety Code Grounding Subcommittee.

He has served on many IEEE committees, participated in the color books (IEEE Recommended Practice), and standards groups, including the Standards Board and the Standards Board's Review Committee. He is a member of the IEEE COMAR, Committee on Man and Radiation and Standards Correlating Committee #28, International Committee on Electromagnetic Safety (ICES). Mr. Zipse received the Standards Medallion for his work in and promoting standards.

He has published countless technical papers on such diverse and controversial subjects as Unity Plus Motors, Computers, Neutral to Ground Faults, NEC Wire Tables, Health Effects of Electrical and Magnetic Fields, Measuring Electrical and Magnetic Fields, Lightning Protection Systems: Advantages and Disadvantages, the NESC and the NEC: Are They Dangerous to Your Health? Electrical Shock Hazard Due To Stray Current and has participated on National Electrical Code panels and in teaching the Code.

He was President of Zipse Electrical Engineering, Inc., an electrical forensic engineering consulting firm. The past fifteen years, he has been primarily involved as a forensic engineer and expert witness in cases resulting from electrical accidents and electrocutions and for the last seven years, he has been engaged in legal cases concerning stray current involving humans and dairy cows. He is now President of Electrical Forensics, LLC.

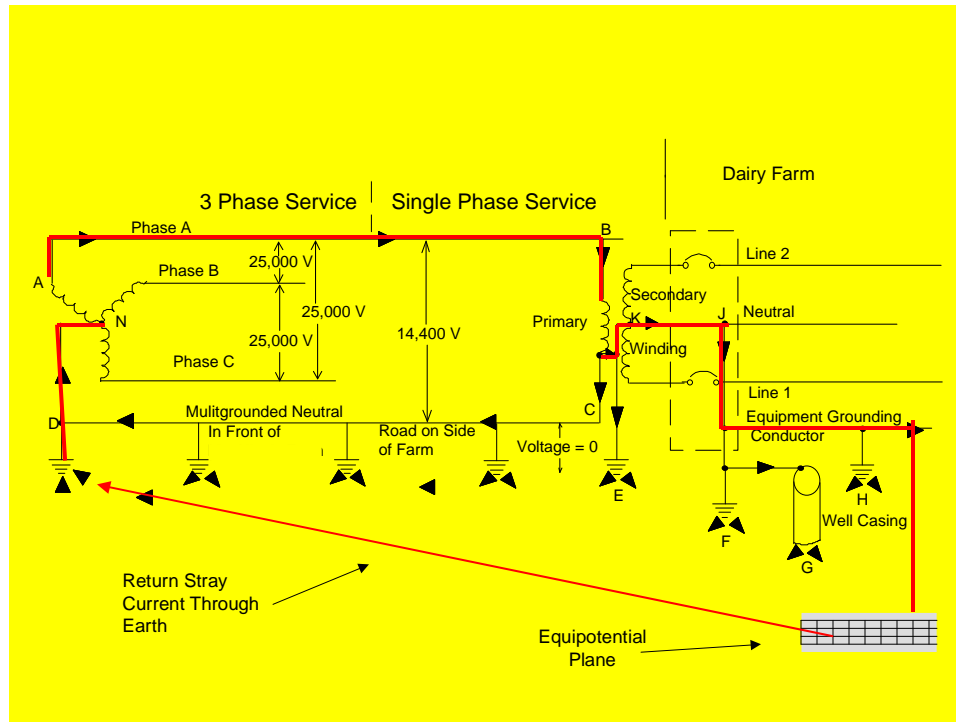


Fig. 1. Stray Current Flow Directly Connected To Equipotential Plane

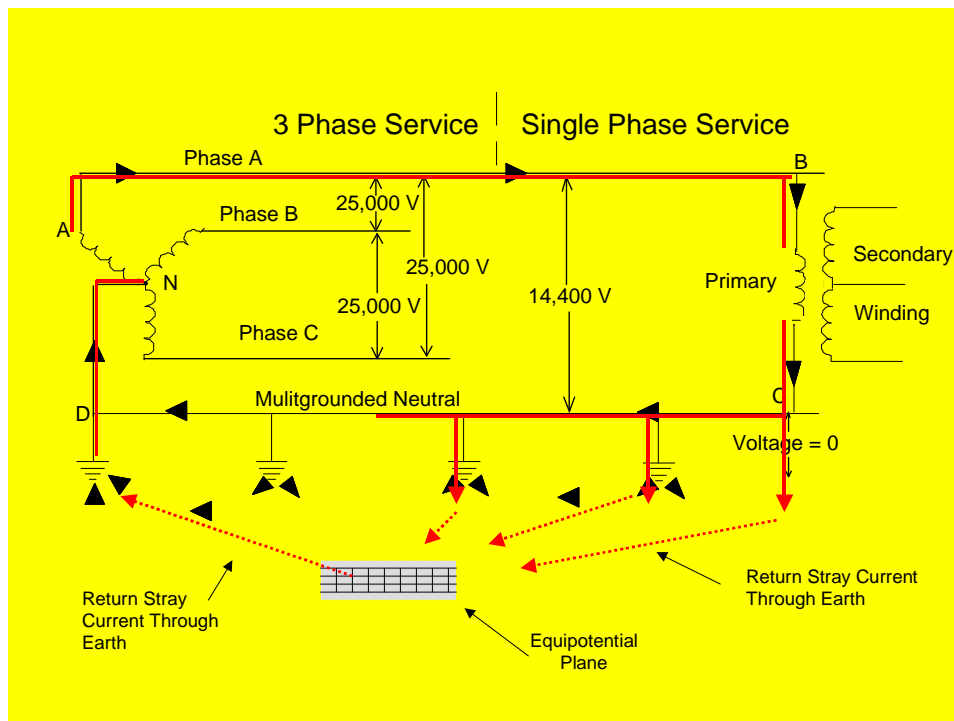


Fig. 2. Stray Current Flowing through the Earth and Through the Equipotential Plane.