

HISTORY OF GROUNDING/EARTHING PRACTICES IN THE UNITED STATES

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Abstract – The history of using the earth as an electrical conductor for man-made electricity for the past 270 years is detailed in this paper. In the beginning man-made electricity used the earth; the surface of the terrestrial ball we live on, as a conductor to return the continuous flowing electric current back to the source for 140 years. Edison realized that using the earth as an electrical conductor presented a health hazard to humans and animals. For a brief quarter of a century the earth was not used as a conductor for continuously flowing man-made electricity. In hindsight, one could reach the conclusion that the lack of knowledge of man-made electricity allowed what seemed to be the correct action at the time, later would prove to be harmful to the human race and other animals. The fascinating history of using the earth for 270 years for conducting man-made electricity has a bright future.

Index of terms- earthing, equipotential planes, Edison, ground, grounding, multigrounded neutral, stray current

Disclosure: This paper contains the opinions of the author who has testified for the plaintiff in cases where utility companies have been the defendant, thus there may be a difference of opinion. The author considers any continuous flow of man-made current in and/or over the earth to be dangerous, hazardous, and unacceptable.

I. INTRODUCTION

The discussion of the "History of Grounding/Earthing Practices in the United States" begins with electrical experiments in Europe and the paper has the following parameters; limited to manmade electrical currents produced from chemical reactions, batteries or generators. Excluded from this paper are static, lightning, solar, fuel cells, wind generation, ac and/or dc high voltage transmission, computer grounding, (see IEEE Standards 142 & 1100), and traction companies, etc. Grounding as required by the National Fire Protection Association's National Electrical Code, Article 250 is not included in the discussion.

Telluric current or earth currents are naturally occurring currents that circulate in the earth's crust, the outermost solid shell, and the mantle which is the area above the core of the earth. These telluric currents are low frequency in the range of 3 to 30 Hz and do not harm humans and animals as has been proposed [1].

The paper is a narration of the significant historical events of earthing/grounding and thus it will be devoid of equations and calculations.

Grounding or earthing of electrical charge has been understood through discharge of electrostatically charged components since the 6th Century BC [2]. According to Lockwood [3], [4], experiments on manmade current flow in earth and or water were performed using scientific methods in July, 1746. Winkler, of Leipsig, charged and discharged a battery consisting of three Leyden jars using the river Pleisse as a return path for the manmade current. Additional verification of the ability of the earth to conduct electricity was attributed to Le Monnier, Watson, Franklin, and De Luc, all making use of electrostatic potential from frictional charging. The use of water and damp ground as part of battery circuits was also studied in 1803 independently by Basse, Erman, and Aldini and in 1808 by Coemmering and Schilling. In 1833, Faraday's note 292 stated "A good discharging train was arranged by connecting metallically a sufficiently thick wire with the metallic gas pipes of the house, with the metallic gas pipes belonging to the public gas works of London; and also with the metallic water pipes of London. It was so effectual in its office as to carry off instantaneously electricity of the feeblest tension, even that of a single voltaic trough, and was essential to many of the experiments [5]."

Grounding or earthing of electrical systems predates Edison's 1882 Pearl Street direct manmade current (dc) generating station by 137 years. A paper titled, "earth Wires; or, the earth as an Electric Circuit Completer" was read before the American Institute of Electrical Engineers (AIEE) in Philadelphia, Pennsylvania in October, 1884 and was preserved in the AIEE's Transactions, Volume 1, paper 8. Thomas D. Lockwood, Electrician with the American Bell Telephone Company stated that "there is no element or adjunct of electrical science more important in many respects than the terrestrial ball itself, when we consider it in its relationship to the electrical circuit . . ." The first recorded use of earth and or water dates back to July, 1746 when in Europe Winkler, of Leipsic, charged and discharged a battery consisting of three Leyden jars using the river Pleisse as a return path for the manmade current. In England in July and August 1747 additional experiments were performed using the Thames and the New River. These results were verified by Franklin in 1748. Thus it was proven that dryer earth and/or water could be used for part of an electrical circuit [5].

One of the earliest examples of the "electrochemical telegraph" was first suggested in 1753 and was developed in 1804 by Francisco Salva Campillo consisting of up to 35 multiple wires. Samuel Thomas von Sömmering in 1809 improved upon the multi-wire telegraph system.

In the United States in 1836 Dr. David Alter, Elderton,

Pennsylvania, which is 60 miles northwest of Pittsburgh conceived and demonstrated but did not develop a single wire telegraph system which used the earth for the return manmade current. Samuel Morse developed an alphabet consisting of dot and dashes, patented in 1837. Steinheil proposed using only a single conductor for telegraph systems in 1838 [6].

The earth "When used in the arts of electrical communication, it enables to reduce one-half of the number of line wires, which would otherwise have to be used; and when we consider the immense number of wires that even now fill our streets and line our highways, we cannot fail to reflect upon what might have been, had we been compelled to provide a separate return wire for each telegraphic and telephonic circuit from 1837 until 1884" [5].

II. EARTHING/GROUNDING OF ELECTRICAL GENERATING SYSTEMS

A. Edison's Pearl Street Central Generating Station

Thomas Alva Edison's successful invention of an incandescent lamp was granted a patent on January 27, 1880, which allowed Edison to form the Edison Illuminating Company in order to use his newly patented incandescent lamp. Edison proceeded to build and install on a new passenger and cargo steamship, SS Columbia being built in Chester, Pennsylvania, USA, in 1880 a lighting system to light the ship [7]. It sailed between San Francisco, California and Portland Oregon.

The world's next Edison lighting system was installed in the printing firm of Hinds, Ketcham & Company in New York followed by the Edison installation at the Holborn Viaduct in London England, which began operating in January 1882 [7]. The first Central Generating Station in the United States was a central power plant at 255 - 257 Pearl Street in Manhattan, New York City, NY (Fig. 1). The Pearl Street Central Generating Station began with one manmade direct current (dc) reciprocating steam driven 110 volt dynamo on September 4, 1882.

It is assumed that Edison was well aware of the testing that was done in Europe proving that the earth and rivers were excellent conductors of electricity and the work on the telegraph system which used a single conductor with earth return. Edison's electrical generation was direct current dynamos consisting of two wires one of which was a positive conductor and the other the negative conductor. Edison's Electrical distribution system consisted of an insulated positive conductor which ran to junction boxes in the street and then into the customers home or business. Edison used the existing illuminating gas piping to run his insulated positive conductor to the existing gas mantle, which he replaced with his electric incandescent lamp.

Edison then connected the neutral return current to the existing gas pipe which entered the earth. At this point this electrical connection of the gas pipe to the earth could be considered the first grounding electrode. Edison used the earth to return the negative current back to the steam driven dynamo at the Pearl Street, Central Generating Station. Edison's use of the earth for the return current conductor caused havoc in the area of his Pearl Street station as related by Tom Shaughnessy:

"Early on, Edison implemented a floating approach for his DC systems after several events demonstrated the adverse effects of stray DC currents flowing throughout buildings and neighborhoods. Once a horse was shocked when it walked on "electrified soil" near Edison's Pearl Street generating station and laborers working on his underground distribution system believe there was a "devil in the wire" [9].

Edison recognized the problem of using the earth to return the current. Five years later on August 30, 1887 Edison was granted patent No. 369,280 titled; "System of Electrical Distribution" which corrected the problem Edison created by



Fig. 1. 257 Pearl Street, Manhattan, in 1882.

using the earth for a return current conductor. On page 2 of the patent beginning with line 31, it reads as follows:

- "All of such conductors from the generators at the station to the lamps are made in pairs – one for the outgoing current and the other for the returning current of electricity, the circuits
- 35 throughout the system being complete or around metal circuits, the conductors of which are well insulated from each other and from the earth. The use of the earth for one – half of the circuit would largely increase the difficult-

40 ties arising from the grounding of the conductors or the crossing of the conductors among themselves or with the conductors of other circuits to such an extent that a system so constructed would be impractical."

Edison, as a result of his electrical shocking problems realized that he could save a conductor by using two dynamos in series with the center point between the two dynamos, being the common conductor (See Fig. 2). Edison recognized the hazards involved in using the earth as a current return path. "The Edison Three-wire System" is described in the Instruction Book No. 8148, published by the General Electric Company in Dec. 19, 1900 and consists of a three wire grounded mid-point at one location only, which supplies phase to phase voltage of 220 and 110 volts for lightning. This is the basis of the electrical distribution in homes today except the single point grounding has not been followed in the present day electrical distribution system. The electrical industry has forgotten what Edison learned 100+ years ago.

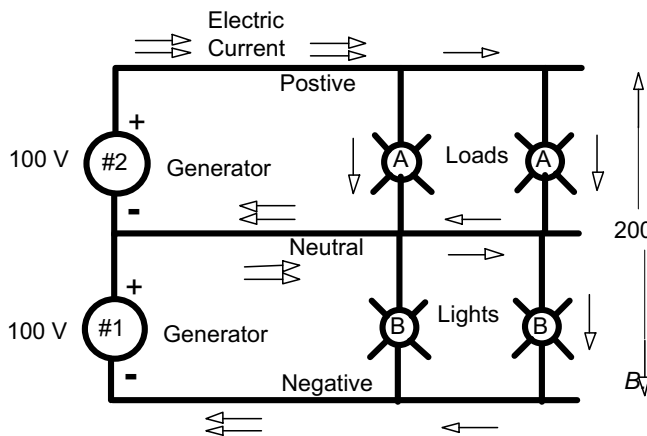


Fig. 2. 3-Wire Direct Current Electrical System with a Conductor Used as Current Return Path

B. Grounding of Alternating Current Systems

Initially the Westinghouse/Tulsa system of alternating current generation was considered unsafe by Elihu Thomson (1853-1937). During an interview by Dr. Edward W Rice, Jr., in 1932, Mr. Thomson states, "We took up the Alternating Current transformer system which I had outlined as far back as 1879 at the Franklin Institute, (Philadelphia, PA). And we built the system but didn't consider it safe until the development of the earthing of the secondary, which was an invention of mine for securing the safety of the secondary lines of the transformer systems" [10].

"One of the reasons why Thomson delayed his application for this celebrated patent on alternating current distribution was his fear that the system would be dangerous when reduced to practice; the insulation of the transformer might break down and the high voltage of the primary would appear in the secondary circuit. It was not until he discovered in 1885 a way to avoid the danger, chiefly by grounding the secondary in the transformer, that he was willing to see the distribution system put into use" [11].

III. CODES AND STANDARDS

A. The Underwriters' Bureau of New England

The National Fire Protection Association (NFPA) can be traced back to a conference of insurance organizations held in New York City, NY on March 18th and 19th, 1896. The first hand-book was written by Everett U. Crosby. The preface states: "This compilation with added new material on the subject of Protection Against Fire is intended as a book of reference for Inspectors and others in the employee of our Members." The 4.5 x 7" book has 183 pages.

Page 163 begins the section titled, "Rules and Requirements of the National Board of Fire Underwriters for the installation of Wiring and Apparatus for Electric Light, Heat and Power as recommended by the Underwriters' National Electric Association, edition of January 1, 1896". As far as grounding is concerned they state under rule "46. a. The wiring in any building must test free from grounds: i.e., each main supply line and every branch circuit should have an insulation resistance of at least 100,000 ohms and the whole installation should have an insulation resistance between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) and not less than the following;" where they have a table based on current from 10 amperes at 4 megohms up to 1,600 amperes and 11,000 ohms.

Note that even in 2017 neutral-to-ground insulation strength is still checked when installing tingle voltage filters and mitigation; often additional wiring on subpanels has inadvertently introduced a ground on the neutral that remains unacceptable in modern wiring codes after 119 years.

The National Electrical Code

The National Electrical Code (NEC) has been sponsored by the National Fire Protection Association since 1911. As the result of efforts of various insurance, electrical, architectural and allied interests the code dates back to the work performed by the National Electric Association in 1897. The NEC, revised every three years, applies to residences, commercial and industrial facilities. It applies to utilities' office buildings and maintenance buildings etc., but not to generation, distribution and transmission lines.

The purpose of the NEC is stated in Section 90-1: "The purpose of this Code is the practical safeguarding of persons and of buildings and their contents from hazards arising from the use of electricity for light, heat, power, radio, signaling and for other purposes."

Section 90-2 covers the Scope: "it covers the electric conductors and equipment installed within or on public and private buildings and other premises, including yards, Carnival and parking lots, and industrial substations; also the conductors that connect the installation to a supply of electricity, and other outside conductors adjacent to the premises; also mobile homes and travel trailers" [12].

Grounding is covered in Article 250-Grounded Conductors and in the 1951 edition was 21 pages long and the book was 4 x 6.25 inches, sized to fit in your back pocket, which was the author's first introduction to the National Electrical Code. The latest edition, 2017 has 31 pages in a book that is 8.5 x 11 inches. To detail the changes in just the grounding article of

the NEC would probably end up as a book and thus the changes to the grounding section of the NEC will not be covered in this paper. The NFPA publishes in each three year cycle a Handbook which explains the changes and the interpretation of the NEC.

C. *The National Electrical Safety Code*

In the beginning of electrical distribution each estate, town or city had its own material and method of installing the conductors and generating equipment; each in their own little area. This resulted in problems due to the lack of uniformity. The National Bureau of Standards (NBS) in 1913 had started to develop The National Electrical Safety Code (NESC). In 1919 the NBS and the National Electric Light Association joined forces and made a survey of the existing electrical distribution systems and found that some areas had unsafe electrical systems. The requirements of the original code were based on good engineering theory and generally accepted good practice.

The publication consisted of separate editions of Grounding Rules, General Rules, parts 1, 2 and 3. In 1972 the NBS resigned from being the Secretariat and the Institute of Electrical and Electronic Engineers (IEEE) became the Secretariat. All parts of the NESC are published together in one document. Like the NFPA the IEEE also publishes a handbook on the NESC [13].

D. *IEEE Guide for Safety in AC Substation Grounding, Standard 80 [14]*

The first edition of Standard 80 was published in 1961. In order to protect workmen within the substation fenced enclosure, a grid of buried copper wires are installed which offer protection against step and touch potentials. The Guide 80 provides considerable detail on increasing the under-foot resistance so as to reduce the flow of current through models of the worker's foot or feet. This grid system is installed over the total area of the substation switchyard and may extend beyond the substation fence.

A typical grid design is based on the maximum amount of fault current expected to flow through the earth when a transmission conductor falls to ground. Since this standard is a "guide" the key word is "may". A typical grid may use 4/0 copper conductor buried 0.3-0.5 m (12-18 in) below grade and spaced 3-7 m (10-20 ft) apart. Under high soil resistivity conditions in areas where persons would walk, a typical mesh would consist of #6 AWG copper conductors in a square grid pattern of 0.6 by 0.6 m (24 by 24 in) installed 0.05-0.15 m (2-6 in) below the earth's surface.

The key points in substation grounding are to 1) protect workers from harmful and dangerous step touch potential, while 2) conducting short circuit current of thousands of amperes 3) lasting for a short duration (seconds) until the protective device clears the fault. Usually primary protection within 3 to 10 ac cycles and backup protection will operate in a modern substation within half a second.

E. *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems, Std. 142 [15]*

The first edition of Standard 142, known as the Green

Book, was published in 1956. The key word in a "recommended practice" standard is "should."

The Standard 142 covers system grounding, equipment grounding, static and lightning protection grounding, connection to earth and sensitive electronic equipment grounding. In the 1991 edition, Chapter 4, "Connection to Earth" details the grounding resistance of a grounding electrode, a ground rod and its sphere of influence.

"As the earth is (relatively) infinite in its size compared to the grounding system as we know them, so too is its capacity to absorb a virtually unlimited supply of current. Practically, however, this unlimited current to the earth is transmitted across the metal electrode-earth soil interface in a way that is best described as follows:

"Around a grounding electrode, the resistance of the soil is the sum of the series resistance of virtual shells of earth, located progressively outward from the rod. The shell nears the rod has the smallest circumferential area or cross-section, so it has the highest resistance. Successive shells outside this one have progressively larger areas, and thus progressively lower resistances. As the radius from the rod increases, the incremental resistance per unit of radius decreases effectively to nearly zero." For additional information consult Chapter 4, "Connection to Earth" [15].

For a typical 16 mm (5/8 in) diameter rod 3 m (10 ft) long; buried vertically in the earth from the surface, would have a sphere of influence extending out 7.6 m (25 ft). A sphere of 3 m (10 ft) captures 94% of the total resistance. (See Section VIII C)

IV. GENERAL PRACTICE REGARDING OPERATING ELECTRICAL SYSTEMS GROUNDED OR ISOLATED NEUTRAL

Figure 3 shows the wiring diagram for an ungrounded delta connected generator or transformer while fig. 4 shows the wiring diagram for an ungrounded wye connected generator or transformer. In Fig. 5 a wye configured generator or transformer is grounded at the source. The neutral is not carried with the phase conductors.

Mr. H. H. Dewey[16] states that from the beginning of power transmission in 1888 or 1890 to 1910 or 1912 that there was no general practice as regards the question of operating electrical systems either with grounded neutral or with the neutral isolated.

"... there was no decided difference in the results of operating either with the neutral grounded or ungrounded. As they (the electrical systems) grew in extent, voltage surges began to make themselves felt over wide areas, resulting in breakdown of insulation at various points"[16]. Any line-to-ground fault on an ungrounded electrical system will result in voltage rise on the ungrounded phases of 1.7 per unit, which can lead to insulation or arrester failure from temporary overvoltage. In the case of neutral instability, during ferroresonance, line to ground voltage can exceed 2.5 times normal voltage on delta systems. In seeking a remedy, many engineers grounded the neutral of their generators or transformers"[16].

The ideal solution would have been to install insulating material of a higher rating; however such a material was not available in 1923. The lack of sufficient insulation to withstand

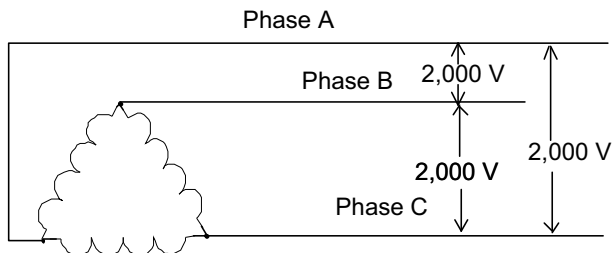


Fig. 3. Electrical System Source Connected in Delta Ungrounded – Not Connected to Earth

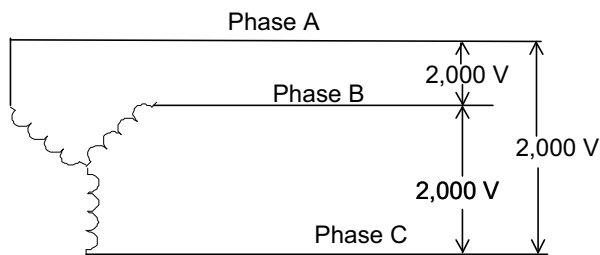


Fig. 4. Electrical System Source Connected in Wye Ungrounded – Not Connected to Earth

the voltage surges resulted in grounding the electrical system at the generator or at the transformers. If more than one transformer were connected to the system for transmission purposes, sometimes each transformer was grounded.

Any arcing fault on an ungrounded electrical system will result in the electrical system voltage rising to two or three times the normal voltage, culminating in insulation failure. Dewey goes on to write, "The evidence was not conclusive at that time and perhaps is not conclusive today (1923), but there are certain fundamental principles that seem to be reasonable definite and most of them tend to show important advantages in favor of the grounded neutral system"[16].

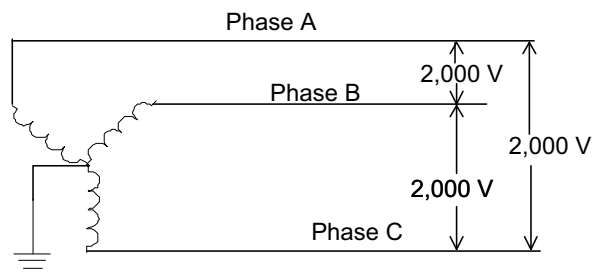


Fig. 5. Electrical System Source Connected in Wye Grounded – Connected to Earth at One Location Only – Uni-Grounded

Note that Fig. 5 is not the multigrounded neutral system. Fig 5 refers to connection to ground of the neutral at the source transformer only or at all transformers.

A. Ungrounded Versus Grounded Wye Three – Phase Distribution Systems

Ungrounded electrical distribution systems, whether single phase or three-phase, presented a problem of locating where a phase to ground fault occurred. The inability to locate a phase to ground fault on an ungrounded electric distribution system resulted in the grounded system being preferred prior to 1923. Ungrounded electrical distribution systems normally would have ground detection lights. A lamp would be connected to each phase and to the earth. The lamp or lamps, depending whether it was a single phase or three-phase system, would be extinguished on the faulted phase. One could distinguish which phase but not where on the distribution system the fault occurred.

A method of temporarily changing an ungrounded system into a grounded system thus enabling the fault to be detected was described by Ackerman [17] in 1923. In the 1950s a pulsing device was developed which when attached to an ungrounded electrical distribution system would put electrical current pulses on the energized electrical system which would allow someone with a sensitive ammeter to clamp around the conductors or if the conductors were in a conduit around the conduit. The electrical pulse would hopefully have a stronger deflection of the ammeter on the conduit containing the faulted conductor allowing one to find the fault location. The present state of the art (2017) in detecting and locating faults on delta systems, ungrounded delta systems and high resistance grounded systems are well advanced.

B. Utilizing the Neutral

In a wye transformer connection the midpoint, the neutral point, can be connected to earth as is shown in Fig. 5 without using the neutral for any electrical loads. Fig. 6 indicates the neutral is also connected to earth, but the neutral conductor is extended along with the phase conductors. The configuration shown in Fig. 6 allows electrical loads, service transformers to be placed between any of the three phase conductors and the neutral.

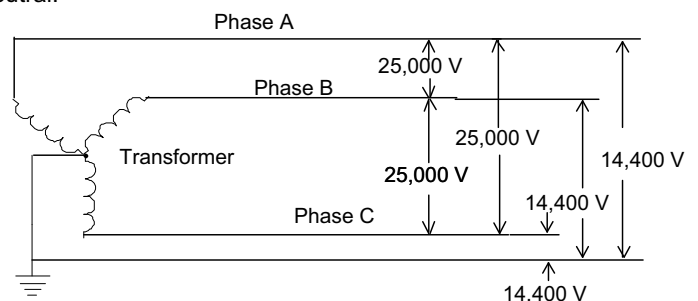


Fig. 6. Electrical System Source Connected in Wye with Neutral Conductor Grounded and a Grounded Conductor Carried with Phase Conductors – Connected to Earth at One Location Only – Uni-grounded

This connection, phase to neutral will force electric current to flow over the neutral back to the transformer. So far, this electrical connection is acceptable, as long as the neutral is insulated or treated as being potentially energized. However modifications will be made in the near future in the name of safety that will negate safety for the human and animals

especially cows in the last half of the 1900s.

In 1914 J. P. Jollyman, et al., writes about the Pacific Gas and Electric Company's practices which include the utilization of the neutral in distribution systems. Transformers are wound for only 57.7 percent of the insulation voltage requirements for a full voltage, phase-to-phase transformer. This amounts to a substantial savings. In addition, there is only one phase bushing on the transformers. This is additional savings over the costs of fully rated two bushing transformer and full transformer insulation rating. The savings equate to additional profits for the utilities [18].

The authors continue to cite additional savings in construction of the distribution line. The pin type insulator, the insulator screwed onto a wooden pin mounted in a cross arm, was the only type that was available in 1904. Savings were generated by applying only 57.7 percent of the voltage rating to the insulator. Instead of having an ungrounded electrical system with 25,000 volts between phases and earth, they now had, with a grounded neutral, only 14,400 volts to earth from any phase. There was still between phases 25,000 volts, but the pin insulator only was stressed to 14,400 volts. This resulted in additional cost savings.

This appears to be a sensible move, but this electrical configuration led later to other problems. In hindsight, increasing the insulation rating would have been the correct method to resolve the problem and protect the public and animals from the dangers and hazards of stray uncontrolled return neutral current flow over the earth.

V. DISTRIBUTION SYSTEMS

A. Multi-grounded Neutral

The next major development in the history of grounding occurred approximately 1915 when it was realized that linemen were being injured and/or electrocuted from working on the neutral barehanded. The neutral was grounded at a single point at the substation transformer and therefore the lineman erroneously assumed that it was safe to handle the neutral conductor barehanded anywhere on the distribution system.

Georg Simon Ohm published the results of his studies of resistance in 1827 defining Ohm's Law where voltage (V) equals the resistance (R) of the conductor times the current (I) flowing in the conductor; $V = R \cdot I$, which applies only to dc.

If we simplify the complex calculations for ac to obtain ease of understanding the problem by assuming that the impedance and capacitance of the distribution lines are negligible we can apply Ohm's law to obtain an estimate..

An example of the problem is if we assume that the lineman is working 5 miles from the substation and the resistance of the neutral conductor between the substation and the lineman was 1 ohm per mile and the neutral conductor was carrying 50 amps, the rise in voltage would be 250 V. It is assumed that based on the average conditions of a distribution circuit at that time it was determined that if the neutral was grounded every quarter of a mile, the maximum voltage between the two grounds would be 35 V. And at that time everyone assumed that voltage was the parameter that would harm humans.

The NESC requires a neutral to have at least four ground connections in each mile. This multi-grounding of the neutral

conductor resulted in what is known as the multi-grounded neutral distribution system. The result is that the neutral conductor is in parallel with the earth and the amount of current entering the earth cannot be controlled and where in the earth these stray current flows cannot be defined. The way the NESC was written you could have four grounds on the first four poles of a mile and meet the requirement. The 2007 Edition correct this oversight, however it is not retroactive.

It has been reported that Professor Charles F. Dalziel, University of California at Berkeley "required" his students to participate in experiments to measure the human animal's response to voltage and current by placing their feet into a bucket of salt water and holding onto a conductor. Professor Dalziel then applied varying amounts of current and measured their response. Mr. Edward Owens, a General Electric Company employee, was a student of Prof. Charles F. Dalziel, confirmed that Prof. Dalziel did in fact have his freshman students participate in determining the level of current that would harm a human

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" [19].

B. Wiring Transformer and Secondary Electrical Systems In 1926

Mr. Post writes about the eastern and southeastern 11 counties of Wisconsin served by Milwaukee Electric Railway & Light Company where there were 21,000 farms. On January 1, 1926 there were only 2,740 farms receiving electric service, 13 percent of the total [20]. The object of the utility was to discourage the use of motors and to encourage the use of lights and electric ranges. Operation of motors was prohibited from sundown to 11 p.m.

Note that in Fig. 7 in 1926 there are two phase conductors supplying the two bushing transformer. The secondary neutral is connected to earth at a remote distance from the pole where the lightning arrester is connected to earth.

"Up to 1923 only about 120,000 of the 6,250,000 farms in The United States had been wired to use electricity." By 1930 according to a radio speech made by the General Electric Company's President over radio station WGY "... shows that only about one-tenth of the farms are connected to public service electric lines and in the second place, that only a small part of the power used on any farm is electric power."

This low usage of electricity continued until late 1930s when there was an increase in the number of farms connected to the electrical distribution systems. There were few electric motors used on the farms. The motors that were used were for water supplies and cream separators [21]. With the low electrical usage the amount of hazardous stray uncontrolled continuous flow of manmade electric current over the farm was much lower than today.

VI. GROUNDING/EARTHING PRACTICES AS OF 1931

A. Types of Grounding/Earthing Methods

The AIEE Protective Devices Committee's Subcommittee

on Grounding in 1923 issued a report on the grounding practices of that day. By 1931 it was felt that there had been sufficient changes in grounding practices that the committee issued a second report. In that report they defined five methods of grounding which are defined as follows:

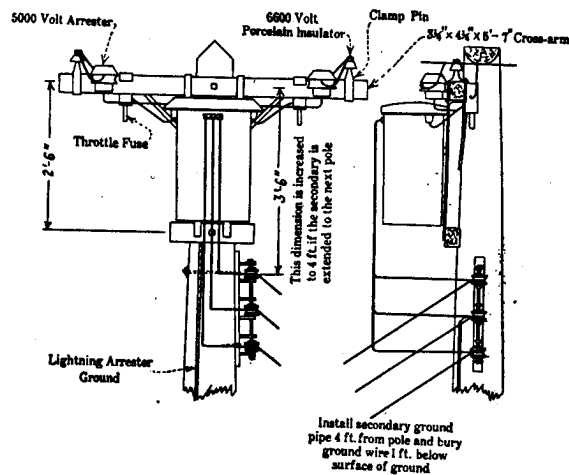


Fig. 7. Pole Mounted 2-bushing Transformer with Lightning Arrester Separately Connected to Earth with No Connection to Secondary Conductors 1926 Era

1) *Solidly Grounded*: A station is considered solidly grounded when the neutral of every generator or transformer bank in that station is connected solidly and permanently to earth through a solidly grounded connection. A system is solidly grounded when all of its major generating stations or transmission substations are solidly grounded.

2) *Resistance grounded*: A station is considered resistance grounded when the neutral of every generator or transformer bank in that station is connected and permanently to earth through a low resistance connection. A system is resistance grounded when all of its major generating stations or transmission substations through a low resistance connection.

3) *Reactance Grounded*: A system is considered reactance grounded when an air core or iron core reactor is interposed between the neutral and earth; if grounded through a grounding transformer or if only a portion of the generator or transformer capacity at any given location is reactance grounded.

4) *Tuned Reactance Grounded*: a system is considered tuned reactance grounded when the aggregate reactive current passed by the neutral reactors or their equivalent substantially equals the aggregate charging current to ground of the system when one conductor is grounded, as with the Petersen coil, Bauch transformer, and the dissonance coil.

5) *Ungrounded*: a system is considered ungrounded when there are no conductive paths between the neutral and earth, except perhaps through potential transformers [21].

VII. 1932 CHICAGO POLE MOUNTED TRANSFORMER FAILURES

In 1932, the City of Chicago pole mounted transformers were failing. The Utilities Research Commission of Chicago

and the Engineering Experimental Station at Purdue University conducted an investigation of surge protection of distribution circuits [22]. Testing involved the interconnection of the primary lightning arrester ground and the grounded neutral of the secondary main circuit.

The conclusions reached were, "Measurements of the voltage between primary phase c lead and secondary neutral have shown that the *interconnection of the secondary neutral with the lightning arrester ground is, in general, beneficial to the transformer.* In particular, with a low resistance secondary neutral ground and a high resistance lightning arrester ground, the interconnection reduced the above voltage by 30 to 50 per cent" [22].

Instead of lowering the lightning arrester's resistance to earth by installing additional ground rods or other methods, the utilities elected to save the additional costs by using the customers' connections to earth. This practice placed the homeowners and the farmers in danger from excessive lightning current flow and the potential of high voltages during the lightning arresters' operations.

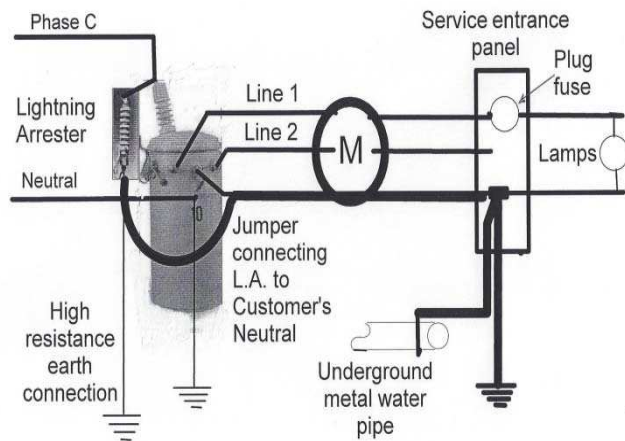
A. Service transformers' Primary Neutral to Secondary Neutral Connection

In 1932 the utilities began connecting the bottom of the pole mounted transformers' lightning arresters to the customer neutral. This practice was intended to facilitate lightning arrester operation by improving the connection of the arrester to earth by utilizing the customers' equipment grounding electrode and/or galvanized metallic piping as in Fig.8. As a consequence, each time the lightning arrester functioned; lightning current would flow into the customer's home. It is opined that the result of a lightning arresters operation could and probably did blow out all the lamps in the customer's home.

It is assumed that the utilities recognized that the cost of electric lamps would prompt their customers to return to their candles and kerosene lamps. In order to keep the electric meter turning thus providing revenue for the utility companies, the utility companies provided free replacement lamps. This practice of the utilities supplying replacement lamps lasted until approximately the 1940s. This was confirmed approximate 2012 when a person overheard the author recounting the 1932 Chicago transformer failure-Purdue University study. This gentleman said that he had to break out the glass from the burnt out lamps on Saturday mornings and give the (brass) shell to his father to take down to the utility company in Chicago on Monday morning and obtain replacement lamps. In addition another person hearing the 1932 Chicago incident stated that his utility in (Kentucky or Tennessee) continued to supply replacement of burned out lamps until the 1960s

B. Pole Mounted Service Transformer Primary Neutral Electrically Connected Solidly to Secondary Neutral

As the result of the 1932 investigation and recommendation that the lightning arrester be connected to the customer neutral has, over the intervening years, morphed into the service pole mounted, pad mounted or underground transformer having a solid electrical connection of the primary neutral to the secondary neutral. This unconventional



sFig. 8. Bottom of lightning arrester connected to customers neutral.

electrical connections allowed primary neutral current to flow unimpeded into and over the customers' wiring, into the homeowner's ground rod, through the metallic water piping into their showers and bathtubs, hot tubs and swimming pools; into the farm and into the dairy barns and milking parlors without the owners' knowledge or consent. To understand and comprehend this situation we need to start at the beginning with what is a transformer.

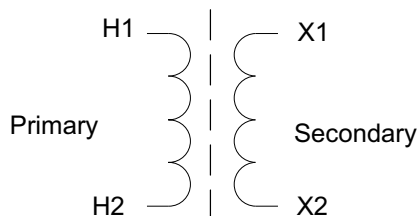


Fig. 9. Transformer Electrically Isolated

Fig. 9 shows what is considered by the majority of electrical engineers as standard electrical transformer connection or wiring. For the purposes of this paper only a customer service step down transformer will be discussed.

In Fig. 10 assume a primary voltage of 14,400 volts is applied to the primary winding and the secondary utility service voltage will be 120/240 volts. Note that Fig. 9 shows a dividing dashed line separating the primary windings from the secondary windings. There are no solid electrical connections between the primary windings and the secondary windings. It is opined that the vast majority of electrical engineers are aware of and considers Fig. 10 to be the correct wiring for a transformer configuration.

Fig. 11 shows the results of the bottom of the lightning arrester being connected to the customers neutral. Present day customer service transformers have either an internal solid electrical connection from the primary neutral to the secondary neutral or the connection of the primary neutral to the secondary neutral is made on the outside of the transformer. One manufacture indicated that 90% of the pole mounted transformers shipped to utilities had a solid internal

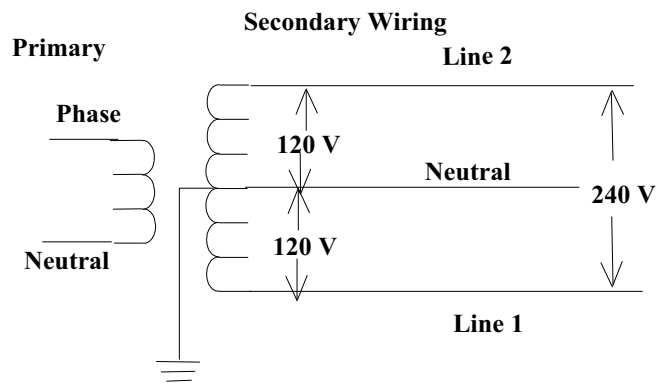


Fig. 10. Phase to Neutral Primary Connection with Secondary winding Center Tapped

electrical connection of the primary to secondary neutral. This connection allows the primary neutral return current to flow in three paths back to the substation.

As the phase current flows through the primary winding at the end of the primary winding according to Electric Power Research Institute (EPRI) only 40% of the manmade phase current (neutral return current) is expected to flow back over the neutral conductor to the source transformer substation [23].

EPRI states that 60% of the phase current (neutral return current) will flow back over the earth through two paths; 1) the neutral to earth grounding connection at the transformer and 2) through the neutral service drop connection, to the service entrance panel neutral terminal, which is connected to the equipment grounding conductor terminal strip. This solid electrical connection of the primary return current neutral to the equipment grounding conductor, the green color or bare conductor, allows the primary neutral return current to enter the internal metallic water piping which in turn can be connected to showers and tubs. The equipment grounding conductor is required to be connected to hot tubs and

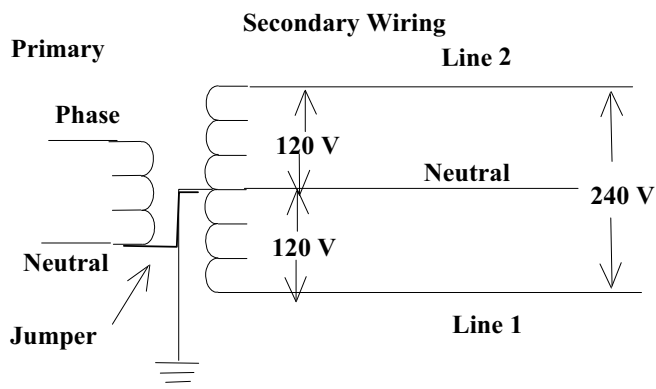


Fig. 11. Phase to Neutral Primary Connection with Secondary winding Center Tapped and the Primary Neutral Connected to the Secondary Neutral.

swimming pools resulting in the potential for electrical shock and potential freezing of a person's muscles causing them to

sink to the bottom and drown.

It is opined that the electrical industry and consumers with sensitive electronic equipment such as computers solid-state controlled television sets, microwave ovens, washers and dryers and other solid-state controlled consumer products are directly connected to the distribution systems neutral conductor which the lightning arresters are also connected. The result is any electrical disturbance such as a lightning strike to the distribution system, a phase to phase fault or phase to ground fault or any other transient generating surge can enter a consumer's home and destroy their solid-state equipment since both the neutral and the equipment grounding conductor may be connected to the electrical device.

VIII. GROUNDING IN THE 1950'S – 1960'S

A. Equipment Grounding Conductor

Knob and tube wiring was the wiring method used until the late 1930s – 40s (Fig. 12) when Romex® type of non-metallic building wire was introduced by Rome Wire Company in 1922. Initially black gas pipe was used, later to be replaced by galvanized conduit which is electrically conductive.

With the return of the G.I., at the end of the Second World War in 1945 a housing expansion occurred starting in the early 1950s, resulted in the demand for electric power tools, which at that time were made of electrically conductive metal. Electric powered tools such as drills, belt sanders and hedge trimmers were wired with two wire cords. Should such a tool become defective and/or a two wire cord severed an energized conductor could contact the metal housing and the person holding the tool would become energized. The only way to protect the person would be for the fault current to travel through the earth back to the source with sufficient amount of current to trip the protective device. The earth cannot be relied upon as the resistance of the earth varies and electrocutions resulted.



Fig. 12. Knob and tube wiring in a 1930 home. View looking upwards at upper wall stud bays and nearby ceiling joists [24].

This prompted the National Electrical Code to require a third wire to be added, the equipment grounding conductor, a

bare or green colored conductor. Naturally it also required receptacles to be three pole.

This requirement for three pole receptacles and an equipment grounding conductor ensured that there would be a low resistance/impedance path directly back to the service entrance panel and no longer relied on the earth to conduct the fault current.

B. Bare Concentric Neutral Conductors

In the late 1950s – 60s proliferation of direct buried bare concentric neutral conductors by the electric utilities occurred in the United States as a cost saving method of electrical distribution. The mistaken idea was that having the neutral in intimate contact with the earth was one of the supposed benefits of the bare concentric neutral construction installation.

NOTE: The author has testified in court in many cases and under oath that both direct buried bare concentric neutral conductors and the multi-grounded neutral distribution system are dangerous and hazardous to humans and dairy cows.

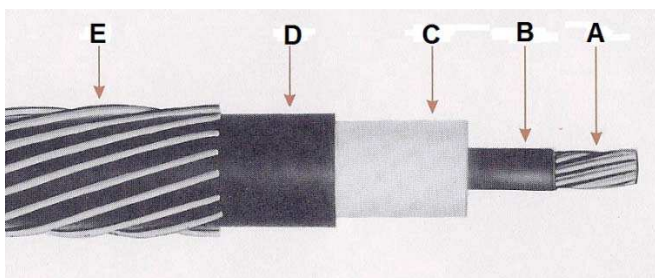


Fig. 13, Bare Concentric Neutral Conductor. A= Conductor-Stranded Aluminum, B = Stranded Screen-Extruded Semi – Conducting, C = Insulation, D = Insulation/Screen-Extruded Semi – Conducting, D = Concentric Wires Bare Copper.

The NESC and the private and investor owned electric utilities condone and justify this dangerous and hazardous type of electrical distribution. However, Rural Electrification Administration (REA) which sets the rules and regulations for electrical cooperatives required in December 1987 that only jacketed concentric neutral conductors could be installed, buried for electrical distribution systems [25].

The installation of the bare concentric neutral has had a devastating effect on the dairy industry, as shocks to dairy cows due to return neutral current inhibit the consumption of adequate quantities of water for milk production. Additionally, shocks due to contact with metal stanchions in the milking parlor prevent the dairy cow from dropping her milk. A dairy cow that is not milked dry can develop mastitis and eventually end up as hamburger.

Four teenagers on March 18, 2006 jumped into a lake south of St. Louis Missouri and were immediately shocked sufficiently that their muscles froze. Three of the teenagers sank to the bottom while the fourth stayed afloat. When he was pulled out he said there was three more in the water. They were able to revive two of the three. The death certificate reads, "Cause of Death: Electrocution contributed to drowning" [26].

The bare concentric underground conductor had 13 number 12 AWG copper conductors serving as the bare

concentric neutral crossing a lake. Four years prior to the incident the bare concentric neutral cable was tested and found to have only three or four number 12 AWG copper conductors remaining. The utility ran on each side of the lake an additional grounding conductor which was connected to the two ends of the cable crossing the lake. The result of connecting an additional grounding conductor to each side of the underwater cable with an open neutral allowed additional return neutral current to flow unimpeded into the water on its way back to the source substation.

C. Grounding Electrode Practices

It was common practice with some engineering firms in the 1950s-60s to have a grounding electrode consisting of 3 – 3 m (10 ft) ground rods on 3 m (10 ft) centers. A sphere of 3 m (10 ft) captures 94% of the total resistance. (See Section III E)

In order to gain the full benefit of a ground rod connection to earth the spacing of ground rods should be based on the depth of rod 1 plus the depth of rod 2. An example would be

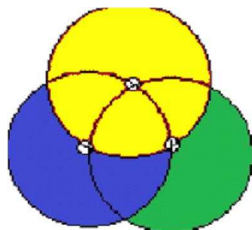


Fig. 14. Overlapping 10 ft Ground rods on 10 foot centers

if rod 1 = 10 ft and rod 2 = 8 ft, then the 2 rods would be spaced 18 feet apart to gain maximum advantage of the connection to earth of each rod.

Before the requirement of an equipment grounding conductor it was common practice to drive a ground rod at each motor thus ensuring that the earth in the vicinity of the assumed electrically faulted motor frame was at the same potential. Since the earth in the vicinity of the electrically faulted motor was at the same potential as the motor frame anyone standing on ground and touching the motor frame should be at the same potential and should not be electrically shocked.

IX. CONCRETE ENCASED REBAR AS A GROUNDING ELECTRODE – UFER GROUND

Mr. H. G. Ufer discovered concrete encased reinforcing bar made an excellent connection to earth. Starting in 1942, he studied 24 buildings in Tucson and Flagstaff, Arizona, USA with reinforcing rods in the foundations. Arizona is normally dry, with less than 0.3 m (1.0 Ft) of rain per year. He checked the resistance reading to earth, once every two months, for over 16 years. The maximum reading was 4.8 ohms with the minimum 2.1 ohms and the average value for the 24 buildings was 3.6 ohms. He presented his findings in 1961, at an IEEE conference. A technical paper presented in 1970 by Messrs. Fagan and Lee [27] proved the validity of the method. The NEC adopted the method thus providing general acceptance of the reinforcing bar for an earth electrode [28].

Concrete above the earth acts as a semi-insulator, whereas concrete below the earth is a semi-conducting medium. It has been shown that each footing or foundation has a resistance lower than a single driven rod of the same depth. With the large number of footings or the long length of a foundation, the total resistive connection to ground is lower than that provided by any other non-chemical electrode. In tests made at Las Vegas, NV, the most efficient method of connecting to earth, excluding the chemical earthing electrodes was the concrete encased electrode for all types of locations [29]. The resistance is generally 2 ohm or less for a structure.

The key to an efficient connection to earth is to have either the reinforcing rod or a length of bare copper conductor, in place of the reinforcing rod, at the bottom of the concrete. The minimum length of rod or conductor needed is 6.1 m (20 ft.) and it should be placed within or near the bottom of the concrete. The conductor should be surrounded by at least 51 mm (2.0 in.) of concrete. The reinforcing bar should be at least 12 mm (0.5 in.) in diameter. If bare copper conductor is used, it should be not smaller than 20 mm² (# 4 AWG)

The Ufer grounding system is the second most effective earthing method. The chemical rods are the most effective; however they need to have their chemicals replaced periodically, whereas the Ufer system has no maintenance requirements

X. EQUIPOTENTIAL PLANES

Unfortunately those that coined the term “stray voltage” failed to realize that voltage is measured between two fixed points that are not straying. It is the neutral return current in the circuit that strays uncontrolled through the earth on its way back to the substation transformer that supplied the phase current.

The preeminent professor Charles F. 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” [33]. It is opined that the U.S. Department of Agriculture, the American Society of Agriculture Engineers and others who coined and use the term “stray voltage” in the late 1970s in reference to dairies, failed to do adequate research on the subject.

“In the early 1980s, three papers on equipotential planes and dairies were written based on, it is opined, a misunderstanding. Gustafson, Surbrook, Reese, Cloud wrote about and coined the term “equipotential planes” [30], [31], [32]. In the author’s opinion in each of the documents the incorrect term, “Stray Voltage” appears and unfortunately, the introduction of “equipotential planes” appeared. It is this author’s opinion that confusion and misunderstanding existed in their interpretation of the Institute of Electrical and Electronic Engineers’ (IEEE) Standard 80, “Guide for Safety in AC Substation Grounding” where step – touch potentials are covered and the NEC Article 250 where “bonding” is covered and the desire to protect cows from electric shocks.

“In 1985, the Ad Hoc Subcommittee on Electrical Grounding of Agriculture Buildings submitted proposal # 19-16, Log # 1363, which can be found in the 1985 Report On Proposals for the 1987 NEC. The proposal was to modify the 1986 Edition of the NEC, Article 547, Agriculture

Table 1 Comparison of IEEE Standard 80 and Equipotential Planes

	Std. 80	Equipotential Plane
Object	Protection Step-Touch	No Voltage Gradient
Current Condition	Fault	Continuous Flow
Available Amperes	$> 10^3$	$< 10^{-2}$
Voltage	$< 35 \text{ V}$	0.0 V

Buildings. This proposal put forth the idea of equipotential planes based on the above equipotential plane papers by Gustafson, et al. Since the proposal came from a subcommittee, it was adopted by Panel 19 "Unanimously Affirmative".

"It has been opined that the lack of understanding of 1) Ohm's Law and 2) the concept of step-touch potential and 3) misunderstanding of the concept of bonding has led unfortunately to the universal acceptance without question of validity, of the equipotential planes for Agricultural Buildings and later for swimming pools" [34].

The equipotential plane concept was proven false by placing a dairy cow on an equipotential plane with a plastic bucket of water and measuring the current flowing through the cow and the water. One must take into account the total electrical system, including the distribution system, the service transformer, the service drop, the service entrance, the equipotential plane and the equipment grounding conductor, the green color insulation or bare conductor. The primary neutral return current conductor is connected directly to the equipotential plane as a result of the 1932 Chicago pole mounted transformer lightning arrester fiasco. (See section VII)

The other way that the equipotential plane can become energized is from stray current flowing through the earth from the multi-grounded neutral distribution system. (See section V)

Unfortunately equipotential planes were adopted for use in swimming pools. Numerous investigations of supposedly drowning deaths in swimming pools revealed that prior to the drowning; swimmers were reporting fish biting them. The sensation of fish bites were the results of nicks and scratches in the swimmers skin allowing the stray current flowing in the swimming pools to electrically shock them. It was surmised that the swimmer's muscles froze, sunk to the bottom and drowned due to being electrocuted. (See VIII, C)

XI. MULTI-GROUNDED NEUTRAL DISTRIBUTION SYSTEM MISCONCEPTION - BALANCING PHASES

There is a misconception that balancing a three-phase multi-grounded neutral distribution system will eliminate stray neutral return current from flowing over the earth. This was proven to be incorrect from testing conducted November 10, 2010 using recording ammeters installed on the three phase

conductors and the neutral conductor. The recording ammeters were installed approximately $\frac{1}{2}$ mile (0.8 km) from the substation where all three phases and the neutral were available. Readings were taken every five seconds and the 12 readings were averaged and recorded every minute from November 10, 2010 at 2:24 PM until November 16, 2010 at 1:25 PM.

Approximately a mile away from the substation phase A went to the west while phase B went to the north and phase C went to the east. Since this was a multi-grounded neutral distribution system, current was injected into the earth in the west, north and east in varying amounts. The electric utility balanced the three phase currents almost perfectly at the point where the recording ammeters were located.

From the measured phase currents the equivalent total neutral current was calculated. The measured neutral current was subtracted from the actual calculated total neutral current, which revealed stray neutral current returning over the earth was 25% of the of actual calculated total neutral current.

Only 75% of the total calculated neutral return current based on the measured phase currents was returning over the neutral conductor. (See VII, B. EPRI)

The above testing proved that stray return neutral current occurs when the three phases are balanced at the substation or any point before the phases split to go in different directions negating the theory that balancing a three-phase multi-grounded neutral distribution system that splits into single phase distribution will not produce stray current, when in fact it does produce stray current.

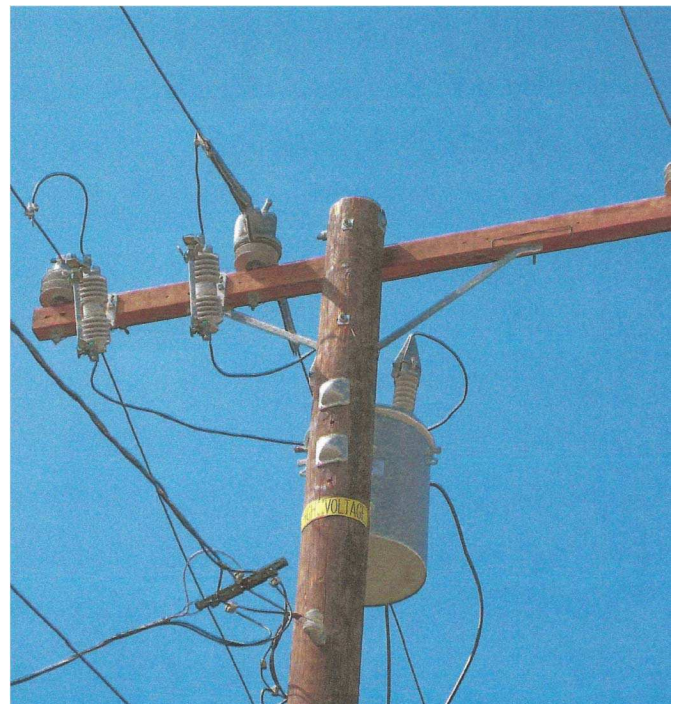


Fig. 15. Newly installed customer service transformer on 6-16-14

XII. THE FUTURE OF GROUNDING

There is a silver lining to the future of electrical distribution in the United States. The author has testified in court that he never expected to live long enough to see the demise of the multi-grounded neutral distribution system. However, in December 2012 a large electrical utility company in initial response to a legal complaint involving three families replaced the multi-grounded neutral distribution system customer service transformers with primary neutral connected to the secondary neutral with new transformers and a different distribution system for each family home [35]. The new customer service transformers were connected to a three-phase, three wire distribution line, wye grounded at the substation only, without a neutral conductor. Using two-bushing single phase customer service transformers, connected phase to phase on the primary, eliminates the dangers and hazards of both the multi-grounded neutral distribution system and the primary neutral to secondary neutral connection that had been in place since the original installation in the 1960s, Fig 15.

XIII. CONCLUSIONS

It is opined that many working in the electrical field think that the earth is a sponge that can absorb man-made electricity. Man-made electricity used the rivers and earth to return electrical current to the source for the first 141 years. Edison's first systems of electrical distribution in the United States used the earth to return the negative dc, which shocked and injured humans and animals. Edison corrected his error in his 1887 Patent: "the conductors of which are well insulated from each other and from the earth". For the mere 28 years, 1887-1915, the earth was free of dangerous and hazardous uncontrolled stray man-made electrical currents.

Electrical codes and standards began as early as 1896. The National Electrical Code covers residential, commercial and industrial facilities and is updated every three years. The National Electrical Safety Code is used by electric utilities and is updated every five years. It is opined that unfortunately there are electrical practices that can harm humans and animals contained in both the NEC and the NESC that should be corrected.

With the advent of multiple phases the practice of grounding the neutral at the supply transformer only, came into use in the early 1900s. This reduced the electrical stress on the equipment and saved countless of dollars in electrical equipment and installation.

The lack of knowledge of Ohm's law, and the laws associated with alternating current and that current and not voltage was the hazardous parameter of electricity led to the development of the multi-grounded neutral distribution system. The multi-grounded neutral distribution system has plagued humans and animals in the United States since approximately 1915 with the flow of manmade stray currents in the earth of uncontrolled magnitude, location and distribution.

The 1932 Chicago pole mounted transformer lightning arrester problem and the adverse effects of connecting the bottom of the lightning arrester to the customer neutral has resulted over the years in the primary neutral of the customers

pole mounted transformer being solidly electrically connected to the customers neutral conductor allowing primary neutral return current to flow into the customers electrical system and into the equipment grounding conductor. The equipment grounding conductor, the bare or green conductor, is attached to metal enclosures that are accessible to the occupants can electrically shock and or electrocute them in bathtubs, showers, hot tubs, swimming pools and lakes [26]. In addition, the stray uncontrolled return neutral current has harmed dairy cows to the extent that the dairies have gone out of business [34].

In addition, the 1932 Chicago pole mounted transformer lightning arrester problem has played havoc with solid-state consumer equipment as any lightning surge or other transients can flow from the primary neutral conductor, to which lightning arrester's are connected, directly through the primary to secondary neutral connection of the service transformer into residential customers homes and commercial establishments where solid-state equipment such as television sets, computers, and other solid-state controlled consumer goods can and has been severely damaged.

The introduction of the third conductor in the 1950s, the equipment grounding conductor which was either bare or with green color insulation, has saved many lives. The expansion of that concept with the advent of the equipotential planes grounding has had the opposite effect in that humans and animals have been not only electrically shocked, but have been electrocuted. It is human nature to deny that mistakes have been made in both the NEC and the NESC with regards to the equipotential planes and multi-grounding neutral distribution. It is opined that there are few humans with strength of character to rectify previous mistakes in either the NEC or the NESC. This statement is based on the fact that it took 21 years, seven cycles to have the equipment grounding conductor, the bare or green conductor, installed on electric ranges and electric dryers. Proposals to remove the dangerous and hazardous equipotential planes from swimming pools and dairy facilities have been rejected when proof that they failed to accomplish protection from voltage gradients

The future of electrical grounding/earthing and electrical distribution holds great promise as in 2012 the first step was taken on the path to eliminate the dangerous and hazardous multi-grounded neutral distribution system by a large investor owned electric utility. In 2014 a complete multi-grounded distribution circuit emanating from a substation was converted to a safe electrical distribution system consisting of 3-wire, three phases, no neutral conductor, with the circuit grounded at one location only, at the wye grounded substation transformer, with phase to phase customer service transformers using two bushing phase to phase transformer connection thus completely eliminating the obsolete, hazardous and dangerous multi-grounded neutral distribution system and service transformers with primary neutral connection to the secondary neutral. The author never expected to live long enough to see the multi-grounded neutral distribution system and service transformers primary neutral connected to the secondary neutral eliminated.

There is the possibility of a bright future for grounding/earthing and man-made electrical distribution systems with the elimination of man-made stray electrical current by the elimination of multi-grounded neutral

distribution systems and the elimination of the primary neutral to secondary neutral transformer electrical connection, allowing the surface of the terrestrial ball we live on to be free of uncontrolled stray current flow..

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XVI. VITA

Donald W. Zipse (S'58-M'62-SM'89-F'94-LF'97) graduated from the Williamson College of the Trades previously known as 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 companywide electrical specialist.

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.

Mr. Zipse is a registered Professional Engineer. He did represent the IEEE on the National Electrical Code Making Panel #14, Hazardous Locations. Presently Mr. Zipse represent the IEEE on Code Making Panel 7, previously CMP 19, Agricultural Buildings. 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.

Mr. Zipse 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 and engineering consulting firm. The past 25 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 15 years, he has been involved in legal cases concerning stray current incorporating humans and dairy cows. He is now President of Electrical Forensics, LLC.