EFFECT OF THE POWER SYSTEM GROUNDING ON POWER QUALITY

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ABSTRACT
Many of the power quality problems suffered by industrial, commercial and domestic customers are caused by the adopted grounding scheme. Power quality problems range from just a sensitive equipment dropout to appliance damage. Also, there are several problems generated mainly by three power quality issues – overvoltages, harmonics, and unbalance – which have a crucial effect on the grounding behavior. The problems generated during a primary fault by the utility-transformer grounding – and their transmission towards the customer circuit – are analyzed. The analysis includes the lightning hitting the lightning-rod into the low-voltage circuit, passing through the surge protective device at a larger magnitude. Several examples describing the equipment damage risk and actual solutions are given in the paper. Also, some conflicting aspects between sensitive-equipment operating conditions and personnel safety against electric shocks are discussed. The effect of the harmonics (triplens) circulating through the neutral and/or protection conductor is analyzed mentioning the filter phenomena presented by these current paths. Due to the wide application of communication systems operating at high and very high frequencies, parts of the grounding circuit are becoming more an antenna rather than a single conductor. Advantages and disadvantages of the “isolated grounding” are discussed for its application to highly sensitive equipment, such as control machine tools. Practical situations are given in the paper, describing the problems and their adopted solutions. It is concluded that although circuits are built according to the installation regulations, problems of grounding and power quality are frequently arising today.

Keyword–*Grounding, transients, overvoltages, Power Quality.*

I. INTRODUCTION

Nearly 80 % of the Power Quality problems are due to deficiencies in the wiring and more specifically to grounding, problems that are solved with relatively low cost if it is compared with the costs of the mitigation equipment [1]. The grounding is the intentional linking of a conductor to earth, which is direct if it is carried out without interposing any impedance, otherwise it is indirect. The primordial objective of that grounding is the protection of the human life, equipment and the electric systems. The dimensioning of the power and protection wiring fulfilling the local and international specifications, not always avoid Power Quality problems, since in such standards their special requirements are not generally taking into account. The wiring mistakes are frequently so simple as caused by an unfastened connection, neutral of insufficient cross section, incorrect grounding or for a damaged conductor. The priority in the design of the wiring is the security and personal protection, so that any necessary modification from the point of view of Power Quality should not put personnel in risk.

II. GROUNDING FUNDAMENTS

The appropriate grounding of the electric systems is critical to achieve its effective and sure operation. When electric systems are considered, besides the electric power system (50 or 60 Hz), also should be included the telephone systems and the telecommunication systems.

The four main functions of the grounding are:

- To protect people and animals from the electrocution risk and to the equipment from damages for short circuits and overvoltages.
- To supply a zero reference point.
- Control of noises.
- To offer a path to earth for the lightning currents and for any fault of the type of surge.

The grounding types are classified as:

- Of service or functional grounding: it is for example the grounding that maintains the potential of earth of the feeding circuits, which is connected to the star-centre of the secondary winding of the distribution transformer.
- Protection grounding: it is where all the conductive elements that can enter in contact with the active parts of the installation are connected, in order to protect people against direct electrical contacts.
- Reference grounding: it is the one in charge of offering constant potential for earth reference to equipment that require it for their operation.
- Grounding for lightning discharges: it is the one in charge of taking to earth the currents of the atmospheric discharges [2].

Figure 1 shows clearly the risk of electric accident in presence of faults, for example, of motor insulation, when this is not appropriately grounded.

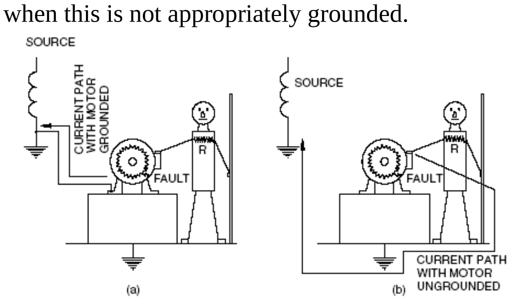

Figure 1, Risk of electric accident when a motor insulation fault takes place (with and without appropriate grounding).

III. REQUIREMENTS OF THE DIFFERENT PARTS OF THE INVOLVED SYSTEMS

III.1. Power System

The power system from the source to the low voltage load can be divided in five levels, denominated: Generation, Transmission, Sub-transmission, Distribution and Secondary System. Each one of these five levels possesses their own requirements nevertheless in what concerns to the grounding for the present study, it will be divided in just two portions, those corresponding to the utility's system and the customer's system. The fundamental differences between both systems are the voltage levels and the circuit topology. The customer's system usually operate with voltages lower than 660 V (380, 230 or 110 V) and having radial circuits; on the other hand in the utility's system very high voltages are used (several thousands of volts) and besides radial and meshed circuits are used. The customer's system possesses circuits as much three-phase as single-phase, on the other hand the utility's system is always of three-phase type.

a. Utility Circuit

Practically all the generation companies connect its generators to earth, for security and better protection reasons. This uniformity of approaches vanished when transmission and distribution systems are considered, since the utilities use one of the following grounding systems: IT, TT or TN [3]. Where the first letter indicates the grounding condition of the energy source, "T" means direct grounding, "I" indicates isolated or grounding through impedance. The second letter, gives the grounding conditions of the protection conductor of the installation, being N an indication of the connection of the protection conductor to the functional grounding.

The interest of this article, resides in the last part of the utility's system, that is to say the distribution and the secondary system, for its direct interaction with the customer's circuit that is where "final use equipment" are located. The "final use equipment" denomination includes all the equipment that transforms electric energy in another type of energy of direct application, equipment that are seriously affected by the Power Quality [4].

The great majority of the utilities, in their distribution systems use four conductors, with the neutral conductor grounded in their start from the transformer star-center and also in periodic form in their way along the line [5, 6]. The specified earth resistance values are very dissimilar varying from 1.5 ohms for Transformer Stations, changing to 5 ohms for pre-assembled overhead lines and Substations, also can be 10 ohms for medium voltage overhead lines, and in some odd cases it is indicated no higher than 25 ohms. Frequently, the grounding in the substation is carried out by using ground rods or an earth mesh, reducing this way the impedance for atmospheric discharges or fault currents, also diminishing the possible induced voltages due to other causes. The rigid joint connection or through an arrester, of the service grounding and the protection one at the transformer substation it is under discussion from the birth of the electric systems. The existence of this discussion, with defenders and detractors of each one of the methodologies, shows that the necessary forcefulness of arguments does not still exist toward a side or another.

b. Customer's circuit

The low voltage electric distribution system more used is of the TT type. That is to say, with the transformer star's centre rigidly connected to earth and with the protection conductor grounded at the building inlet point, like it is shown in Figure 2 [2].

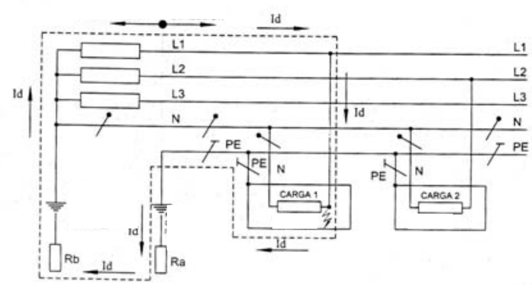

Figure 2, TT System as used in many countries, including Argentine [2].

When the TT system is used it should be very clear for the customer that the fault currents that can circulate are quite smaller than the short circuit currents, what is completely different in the TN systems. For it, in the TT systems it is necessary the use of differential current circuit breakers with sensitivity lower or similar to 30 mA. The user's circuit grounding possesses characteristics and objectives different to those corresponding to the utility, since now it is not the only system in charge of offering a path to earth to the atmospheric discharges and fault currents [7]. Its main objectives are the protection of people and equipment, and to give a zero reference for power and signals. The main fact is to avoid the presence of elevated contact voltage that is to say to reduce the potential between two conductive surfaces that can be touched by people. Floating conductive points should not exist in the vicinity of electric circuits that is in the event of an insulation fault, a path should be provided so that the current can flow easily to earth, as it is shown in Figure 2. This path to earth should be guaranteed by the existence of insulated specific conductors (some standards allow the conductor not to be insulated), since this crucial guarantee cannot be left only in hands of the continuity of the mechanical protection of the electrical circuit (pipes, boxes and enclosures in general) where the wiring is located. The specific conductor for the guarantee of

the path to earth is denominated "protective conductor". This path should also assure the fast operation of the overcurrent protection in the event of a fault to earth, reducing this way the time of presence of contact potential different from zero, being 24 V the limit of voltage for permanent regime [2]. The protective conductor and its connections, can be less robust than those of the phase conductors, inside limits specified in the regulations (most of the regulations specified as minimum cross section 2.5 mm^2), because this conductor do not drive current in continuous form.
The normal grounding practice in domestic circuits, consists on using a ground rod at the start of the circuit or at the power inlet point, which is frequently also connected with the water pipes, if these are (and they will continue being it) metallic. The dimensions, location and other constructive data of this grounding are usually specified by the utilities. The grounding resistance value is normally not directly specified, but through the value of the possible contact voltage and duration of its presence. For the names given in the circuit shown in Figure 2, being I_d the fault current and R_a the protection grounding resistance, three situations are presented:
- I_d x $R_a \leq 24$ Vac without duration limitation,
- 24 Vac $\leq I_d$ x $R_a \leq 50$ Vac limited to 5 s for the operation of the protection, and
- 50 Vac $\leq I_d$ x $R_a \leq 230$ Vac limited to 0.17 s for the operation of the protection.

These situations lead to the necessity of the utilization of differential protection, being able to affirm that in general, the value of the protection grounding resistance should not be higher than 10 ohms, but in condominiums (joint tenancy housings) or in the event of installations with massive employment of sensitive electronic equipment, the value should decrease to 2 ohms [2]. In spite of these specifications, power quality engineers advise lower values, of the order from 2 to 5 ohms and even smaller [1]. The industries with high number of sensitive equipment, can find some difficulties in the use of the TT system, in such a case it is necessary to move to the employment of the TN system [8, 9].
It is usually specified that all the systems and equipment of communications that enter to the building or the structure should possess joint grounding, together with the electric power grounding at the feeding inlet point, what is *unique grounding*, although there are several separate ground rods interconnected by a conductor. This standard is normally not followed in most of our installations; the telephone, video cable, and data cable companies act in arbitrary form, in the best of the cases placing separated grounded as can be seen in Figure 3.

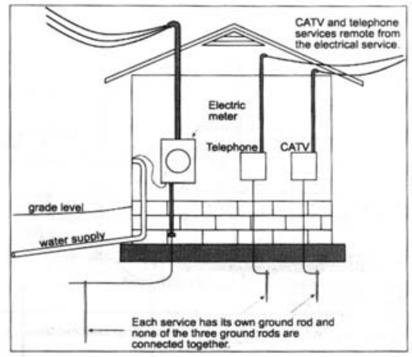

Figure 3, Wrong application having separated grounding the TV, telephone and power systems.

b.1. Customer's grounding considering the Power Quality requirements.
The grounding from the Power Quality point of view not only should offer personal protection against electric shock, but rather it should also control the presence of noises and transients, supplying a system having equipotential bonding. This grounding should provide a low impedance path to earth for a wide range of frequencies. Should be remembered that for higher frequencies, start to be of weight the "skin effect" and the "vicinity effect", besides the long and very inductive conductors behave as practically an open circuits, acting as true radio-frequency antennas.
From the point of view of Power Quality, the biggest grounding issues are: earth loops, noise of electromagnetic interference, loose connections, poor earthing, lightning, neutral conductor of insufficient capacity, loss of protection ground, redundant ground rods, etc.
Of these problems, the most serious is the one caused by earth loops that exists when two or more points of an electric system that are nominally to earth potential, are connected by a conductive path, in such a way that current will circulate when one or both of them are not to the earth potential [10]. Figure 4 shows the case of two sensitive devices interconnected by a signal conductor whose earth connections can be at different potential, originating an earth loop where some current will flow. Some normalizations demand an only point of union among the neutral and earth that is in the energy inlet point of the customer's installation [11]. The more used regulation specifies the existence of only a grounding point in the power inlet and without joining it to the neutral conductor [2]. If there is more than one connection to earth, several paths will exist for the fault currents, harming this way the operation of the overcurrent protection for division of currents; and in the event of discharges dangerously high voltage potentials can appear inside the installation.

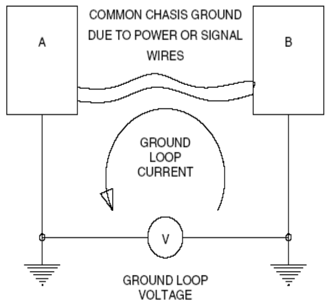

Figure 4, Voltage and current generated by the existence of an earth loop.

b.2. Multi-port equipment

In the multi-port equipment, that is having a port for power entrance and one or several other ports for signals, each one of these circuits possesses their corresponding grounding, in such a way that exists high probability that earth loops can be formed (Figure 3). Also, the multi-port equipment work interconnected with other similar multi-port elements; therefore it is highly possible that they have their chassis (grounded parts) at different voltage potential, thus generating earth loops. The chassis of the equipment is the metallic part that is internally connected to the protective conductor.

The magnetic coupling between the phase conductors and the earth conductor, gives place to the appearance of small currents that perfectly can be neglected. On the other hand, high magnitude and highly harmful currents are generated when two points of the equipment are connected to earth in different locations, being shown in Figure 5 the mentioned situation. The communication conductors among equipment can offer paths to form an earth loop, circulating a current that generates electric noises that can cause operation faults in the logical systems.

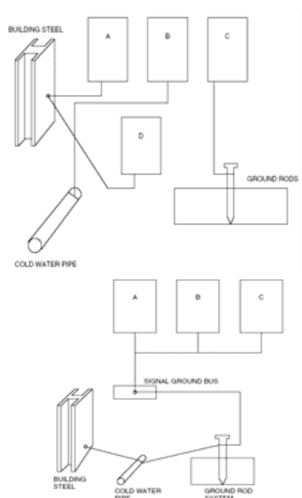

Figure 5, Separated and join earth connections.

For example, two sensitive devices (computers or PLCs and adjustable speed drives) with feeding conductors of different longitude, interconnected by a signal cable, create an earth loop for high frequencies due to the difference in the inductances of the feeding conductors. For it, the high frequency noise signals, will avoid the long feeding conductor, circulating for that of interconnection, giving place to an earth loop, like it is shown in Figure 6. This current circulates inside of the device generating relatively high voltage differences that can damage the highly sensitive microchips.

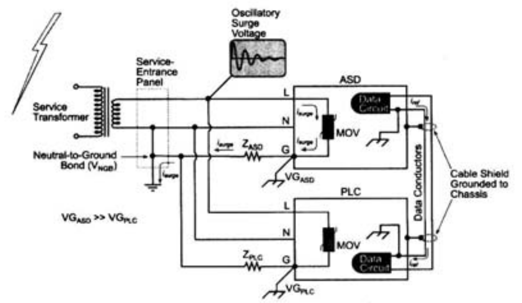

Figure 6, Possible damage due to voltage differences between grounding connections and current circulating through the interconnection shielding.

The current circulation makes the earth conductors to act as loop antennas, transmitting a buzzing that interferes communications signals. The way to detect its presence is measuring the existent potential difference between the neutral and earth or to check that the sum of currents for phases and neutral is different from zero, being justifiable a deeper study when the current value reaches 0.1 A. The solution resides in connecting the equipment to earth in a common point at the inlet location, or to eliminate the long conductors, or using optic conductors for the interconnections or optical-couplers.

The potential difference that is measured among the neutral and earth conductors, can be due to the voltage presence in the neutral or in the grounding conductor. The potential in the neutral can originate in the voltage drop due to the current circulating through it or it can be part of a complex phenomenon that generates common mode noises or signals, as shows Figure 7. The answer to this problem does not usually possess a unique simple answer.

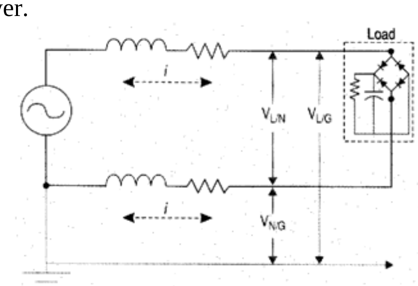

Figure 7, Voltage differences against the protection conductor.

The existent of voltage difference measured between the neutral and the earth conductor in the load side is really the voltage drop in the neutral conductor. As the voltage drop normally accepted in the load it is of about 5%, if it is divided in normal values such as 2% for the feeding and 3% for the sub-distribution circuits, thus the voltage between neutral and earth can be between 5 and 8 V. Some makers of sensitive electronic devices specify supported maximum levels of the order of 50% of those previously cited, for what big conductor cross-sections and dedicated transformers would be required.
Figure 8 shows the schematic circuit of a typical feeding source (commutated type) of sensitive electronic equipment, where it is seen that does not exist components referenced to earth that can be affected by the earth-neutral voltage [12]. The problem resides in the circuits of detection of output and feedback voltages. If the detection circuit of the source output voltage is referenced to the chassis and does not exist the connection of the chassis with the return d.c. current, the neutral voltage will appear as a d.c. voltage fluctuation, causing the equipment incorrect operation. A very frequent problem happens when the source is floating regarding the chassis and it possesses a RS-232 port and the chip for this protocol incorporates internal reference to earth. The neutral potential can cause erratic data transfer and high common mode potentials that can damage or to degrade the chip. This last problem is frequently presented in printers and auxiliary devices.

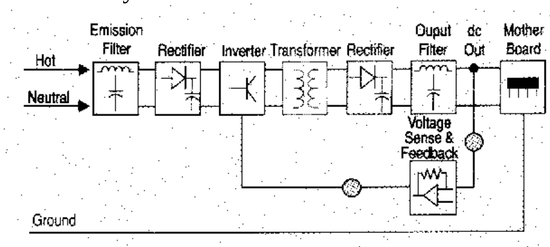

Figure 8, Typical feeding source of a sensitive device.

If the voltages between neutral and grounding conductor are of high frequencies, the problem that is presented is different. Figure 9 shows as common mode true interference the line - earth and neutral – earth voltages, as the earth is the common reference to both conductors, the only possible path for this interference it is through the internal circuit of the device that is referenced to earth. The common mode voltage is just of 50 to 70 V, but the frequency is very high of the order of 20 kHz, what can reset the feeding source or damage the I/O ports like the RS-2322 [12].

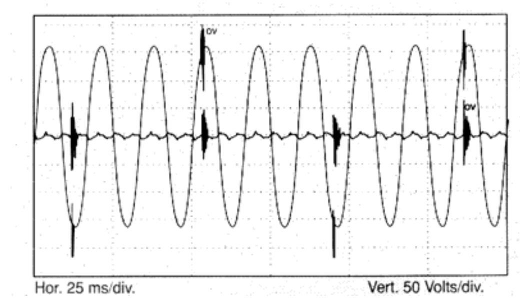

Figure 9, Line – earth and neutral – earth voltages.

This perturbation has numerous paths and also possesses high energy values. This interference type usually passes unobserved as true common mode, since the measurement is normally made among phase and neutral and among neutral and earth, and is not done between phase and earth.
The electromagnetic interference noise is a high frequency signal that appears in lines and in power circuits. It is transmitted in two ways, by the air, on a power line or through the earth. The main effect of this noise is the incorrect operation of the sensitive equipment, being able to mention lines and variable undulations of image in computer monitors and TVs, automatic cashiers' mal-operations, erroneous registrations of petrol sale pumps, etc. The simplest form of eliminating the noise is by increasing the distance or shielding the conductors. In the past the harmonicas of the distribution lines used to interfere the phone lines, problem that practically has disappeared for the use of coaxial conductors and of optic fiber.
The loose connections are many times cause of power quality problems, since they generate surges for interruption of inductive circuits (noise of high frequency) that can damage the sensitive electronic devices. This loose connection can represent a high resistance path to earth, avoiding the dissipation in earth of the energy of discharges.
The atmospheric and electrostatic discharges should be derived to earth to avoid that they affect to the sensitive devices. As both discharge types will follow the less impedance path, these should not go through the sensitive device, since it will instantaneously damage its electronics. If good paths outside of the building of the factory, office, etc. are offered to these discharges and the building possesses the corresponding interconnections to guarantee equipotentiality, an elevation of the earth potential that will also elevate that of the construction as a whole will take place without harmful voltage differences over the devices and without putting personnel in risk. Following the European normalization, the connection to earth for discharges should be connected to the equipotential bar of the building and in that way to the entirety of the groundings of the inlet circuits, collaborating such circuits in offering paths for the discharge, like it is pointed out in Figure 10 [2].

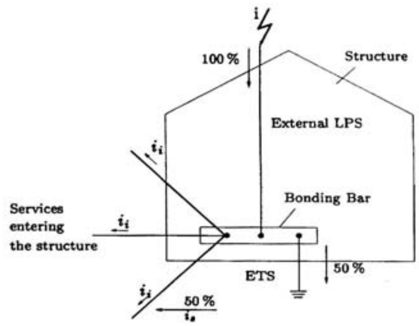

Figure 10, Current distribution following IEC 61312-1.

According investigators, especially from USA, the grounding for atmospheric discharges should be independent of any other earth connection, and its conductors not to come closer to less than three meters of other conductors (power and signal) in order to avoid induced voltages that can damage to the devices connected to such conductors. The same concept is valid for the electrostatic discharges; it should allow their dissipation in earth without going through the device. One of the main origins of these discharges is the charge of the human body, being necessary in cases of high sensitivity the use of elements or measures before touching the device.
The insufficient neutral capacity is mainly presented by two causes. The first of them is due to the loads imbalance among phases whose vectorial addition circulates through the neutral. The second cause is the day by day increasing presence of harmonics in the power systems, among which the most harmful for this study are those denominated triplets harmonics. They represent the third harmonic and their odd multiples that possess the characteristic of being of zero sequence that is to say that they are added in the neutral conductor. With the modern electronic components, especially with the massive use of the commutated sources, these currents by the neutral conductor reach r.m.s values of until two times those of fundamental frequency through the phase conductors, like it is shown in Figure 11.

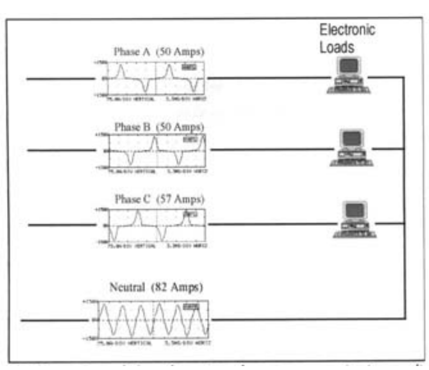

Figure 11, Magnitudes and wave-shapes of the phase and neutral currents of a circuit having electronic loads.

This presence, forces to the over-sizing of such neutral conductors, being suggested that double cross-section that phase cross-section is used for that neutral conductor; or that each phase possesses a neutral conductor of same cross-section that that of phase. If these overcurrents were not considered in the design stage, the consequence is the neutral conductor overheating, conductor that can take fire in extreme cases. In the best of the cases on the conductor will be generated voltage drops of relatively high frequencies that generate electromagnetic interference and also induce noises in the neighbor signal conductors.

III.2. Telephone system

Several of the current electronic devices are connected to the external world via the phone system. Among the equipment used as interfaces with the external world, it can be mentioned: modems, fax, servers, hubs, bridges, routers, etc. All these devices require of protection against overvoltage impulses or surges, either having interior or external origin. These devices, through their external lines, are exposed to direct, induced and coupled atmospheric discharges. Another of the risks that should be considered is the direct contact between the phone and the a.c. power lines.

III.3. Signals and telecommunication systems

The signals systems are today as critical as the power systems, as much for the industry, the commerce and the offices as well as for the domestic circuits. The grounding of the telecommunications systems are of characteristic different from those corresponding to power, mainly due to the operating frequency. The more important problems that affect the Power Quality refer to the presence of noises in the communications circuits due fundamentally to the existence of earth loops, when the circuit has several distributed groundings. The solution to this problem is reached when all the signals systems are connected jointly to earth with the power circuit, in its construction inlet point.
The problems of signals systems grounding, from the Power Quality point of view, have been increased in great measure by the widespread use of PCs, PLCs and other electronic devices that operate with 5 V or even less voltage values. The new generation of these devices has displaced the traditional equipment, such as timers and sequencers that operated with 120 V, which were practically invulnerable to the electromagnetic interferences. It is then fundamental that the non-intentional voltage differences among data processing devices shall be extremely low. The conventional power system grounding should be modified due to the high frequency of operation of the today signal systems, with the consequent reduction in the corresponding wave lengths. At high frequencies the wave length drops, being able to generate resonance in short

length conductors [1]. As the grounding systems are increasing its complexity, there is more than one involved frequency therefore the impedance characteristic as frequency function has the form shown in Figure 12.

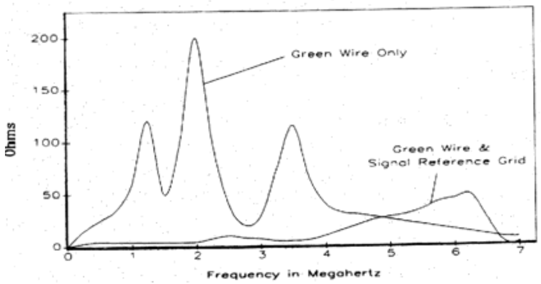

Figure 12, Effect of the frequency on the grounding impedance.

The present operation frequency of the modern PCs, that is to say of their internal clocks is in the order of the radio-frequencies, for what the wiring can act as antenna, responding to external radio-frequency signals, producing erroneous data processing. Besides, wandering or stray inductances exist and parasitical capacities also exist among conductors, between conductors and cabinet. For it is very difficult to avoid the presence of voltage differences between the ends of a conductor connected to two data processing devices, being able to induce processing errors. If high frequency impulses are applied to a conductor, these impulses travel along the conductor being reflected when they reach the end. To certain frequencies, the reflected waves can reinforce the incident waves, creating resonance. The antenna effect should be added radiating or receiving that it can present to the PC a false voltage signal. Such effects are totally unpredictable, since the signals are not recurrent and that besides the sensibility of the processing device is variable. As the microprocessors operate with binary signs (0 or 1, on/off), their maximum sensitivity is presented in the moment of the state change, if at this time some spurious signal appears, a false "bit" can happen. A form of avoiding this problem is by means of the equipotentiality inside the whole operation frequency range, that can be achieved by means of the grounding mesh, similar to which can be seen in Figure 13, with grid of the order of 60 cm x 60 cm. In these meshes one path to earth could enters in resonance to certain frequency, existing several other possible paths that are not in resonance.

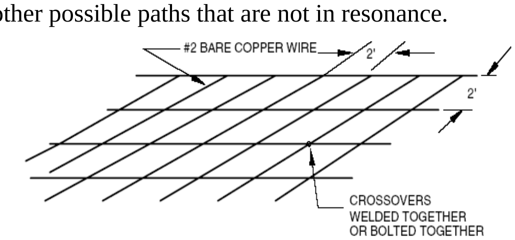

Figure 13, Grounding through a mesh.

IV. WRONG SOLUTIONS

Many electric systems designers and installers applying mitigation measures that really cause new problems. The more widespread wrong measures are: insulated earth, use of additional ground rods and use of multiple connections among neutral and earth. What is more serious, is that some of these wrong measures put in risk the personnel, like it was shown in Figure 1.

V. RIGHT SOLUTIONS

The three basic principles to solve problems of Power Quality (the three "S"), are:

- Separation, Selection, and Shielding.

The *separation*, is usually the most economic and effective measure to solve Power Quality problems. The sensitive and non-sensitive loads do not work very well when they are together, therefore the separation should be made with the phase and with the neutral conductors. For example a motor connected next to a computer, will take it out of service, every time that the motor start for the voltage sag that the overcurrent produces. In this case the solution is reached by feeding the sensitive equipments with a dedicated exclusive line that leaves from the main board, moving up-stream the point of common coupling.

The conductor *selection* is made based on technical and economic approaches, choosing the conductor that is able to drive certain current of 50 or 60 Hz with an acceptable voltage drop. This approach was acceptable until some years ago, but when Power Quality is considered the criteria should be modified. The voltage drops caused by the polluted current, on the increased inductance conductor due to the frequency of the contamination, should not induce harmful noises in the low power conductors.

As more expensive solution, the induction problem can be also solved by means of the employment of better signal conductors, such as: a; twisted conductors, b; coaxial cables, and c; optic fiber, having each of them their own advantages and disadvantages. The best solution is logically the most expensive, the use of optic fiber. It is flexible, of small size but difficult to connect and it requires in each end the converter of luminous into electric signal and also the reverse one. It allows the biggest transmission speed, the higher data quantity and to the biggest longitude of the three mentioned systems.

The electric *shielding* acts like a true "armor", absorbing or reflecting the electromagnetic or radio-frequency interferences. The shielding of a signal conductor is simply achieved by means of a meshed cover. There are other shielding methods for more voluminous elements as equipment, for example to shield a room by means of the covering of the same one with a metallic layer, or in the event of a smaller device it can be internally painted with a conductive paint. The metallic conductive parts where the power and signal cables are lay can act as a shielding, provided the unions and mechanical connections have been carried out keeping in mind their electric continuity to the problematic frequencies. If the protection conductor possesses high impedance, an important part of the current will circulate for the metallic conduit with what the shielding disappears. The conductor's shielding should be grounded in both ends, to assure this way the existence of a low impedance path for the undesirable signals.

VI. GROUNDING MAIN TYPES

The grounding connection for sensitive equipment is suitable when it gives a low impedance path to earth, for a frequency band that ranges from the operation values until the perturbation values. Exist fundamentally three types of grounding: a; ground rods, b; rings, and c; meshes.

a – *Ground rods*: their effectiveness depends on the material, longitude (or depth), shape, number and earth resistivity. It is usually formed by cylindrical bars of copper or steel, recovered with at least 250 µm of copper, buried two or three meters in the floor. The connection ground rod - earth can be studied as formed by a series of concentric cylinders as shown in Figure 15. The earth resistivity of the earth depends on the soil temperature, humidity and chemical composition.

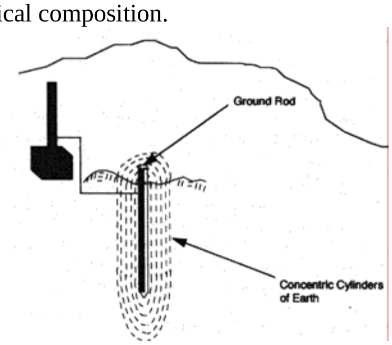

Figure 15, Voltage field distribution in a grounding connection by using ground rod.

b - *Ring*: it usually consists on a conductor having a cross section between 35 and 70 mm^2 that surrounds the construction and it is interconnected with the buried ground rods, and also bond to the iron building structure, and can also be connected to all the metallic pipes. It is buried to a depth between 60 cm and a meter, so that it is below the general level of soil freezing.

c - *Mesh*: it is a mesh of copper conductors with grid of the order from 40 to 60 cm, depending on the construction dimensions, which is shown schematically in Figure 13. It is used as a combined earth connection for power and signal, since for their constructive characteristics, it easily diffuses in earth the 50 or 60 Hz currents, greatly reducing the magnetic field density. For the high frequencies currents, the interconnection conductors equipment - mesh are short and thus of low inductance, avoiding that the conductors can resonate or become radio emission antennas of radio-frequency noise. Frequently the meshes are built inside offices areas (false-floor) or in laboratories or in very "noisy" industrial parts. If all the metallic parts near to the earth mesh are solidly connected to the mesh, the connection is denominated "multiple earth connection".

VII. CONCLUSIONS

The sensitive equipment are affected by the existence of small potential differences between the active conductors and earth (chassis), varying this effect from the service upset (self disconnection) until the damage. This high sensitivity forces to the study of the sensitive equipment behavior for steady state an transients due to discharge and faults. The grounding, with the objective of improving the Power Quality is a complicated task due to the electric power behaves in way very different to power frequency that to the frequencies of the communications systems. The requirements to avoid electrocution risks and of damage for short circuit should also be covered. Thus it is extremely advisable to revise the installation looking for wiring and grounding problems before any advance in the selection and purchase of any mitigation equipment.

IX. REFERENCES

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