Implementation of the TN-C-S Scheme in an Ungrounded Low Voltage Electrical Installation in Manaus / AM

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Abstract

This paper is intended to formulate a hypothesis for the implementation of a grounding system in a low voltage electrical installation in the city of Manaus. According to ABRACOPEL and PROCOBRE 48% of Brazilian properties do not have a protection conductor and according to NBR 5410 and NBR 5419 the grounding system is of crucial importance, both for the protection of the building, as well as the human being; Inserted in this context, the present article seeks to report a method applied by the author for the implementation of a reliable grounding system that fits the Manaus Electric Power System.

Keywords: Electrical installation; Grounding; Low tension.

1. Introduction

The Brazilian Association for Awareness of the Hazards of Electricity (ABRACOPEL) and the Brazilian Copper Institute (PROCOBRE) performed in period of August to September 2016 a field research [1], being validated by the Qualibest Research Institute. This Research found that 48 % of houses and

apartments in Brazil do not have a grounding system. Such a situation carries very serious risks to the life of the human being and to the property as a whole. The annual statistics of ABRACOPEL for the year 2018 [2] reports that 59% of accidents of electrical origin are due to shocks and fires, 38% current overload, and 3% related to atmospheric discharge. Already in the yearbook for 2017 [3] is reported 52 occurrences of death by shock in the northern region, where 13 occur in the state of Amazonas. There are also 58 fires by short circuit in the Northern region, where 18 occur in the state of Amazonas, representing a rate of 31.03%.
The idealization of this article originated from a practical problem that was solved by the author where was required the installation of an electrical device of protection against surge, and for this the grounding conductor was required. It was thought of two method that would solve this problem, however the most easy, trustworthy and safe was the implementation of the TN-CS system, as provided by NBR 5410 [4].
The implementation of this system has serious risks and needs a set of measures to ensure protection. For this reason, this scheme is not very suitable for low voltage installations, however, in this article will be observed the application of this system in the city of Manaus, presenting justifications that guarantee their effectiveness.
This article will be organized through a normative approach on the implementation of this system, highlighting the required requirements and how they will be applied. In another section will be presented the methodology applied in the implementation of this scheme followed by a discussion of the results, where we will have a critical analysis of the safety of this system, inserting analysis parameters of other authors.

2. Theoretical Referential

2.2 TN-CS Grounding Scheme

The grounding schemes present in item 4.2.2.2 of NBR 5410 [4] are divided into three Groups: TN, TT and IT; where the first has three subdivisions: TN-S, TN-C and TN-CS. In line 'b' we have the caption for each letter:

First Letter: State of input in relation to the ground.

- T: A point directly grounded;
- I: Isolation of live parts, or grounding by impedance;

Second Letter: Situation of the masses of the Installation in relation to the ground.

- N: Ground connected to the point directly grounded in the supply;
- T: Directly grounded masses, regardless of eventual grounding;

Third Letter: Arrangement of neutral conductor and protection conductor.

- C: Function of neutral and protection combined in one conductor (PEN);
- S: Neutral and protection function provided by different conductors.

The TN-CS scheme has function of neutral and protection combined in the same conductor in part of the installation, in other part, we have its separation. As a rule, this separation should always occur posteriorly. The standard scheme can be seen in Figure 1:

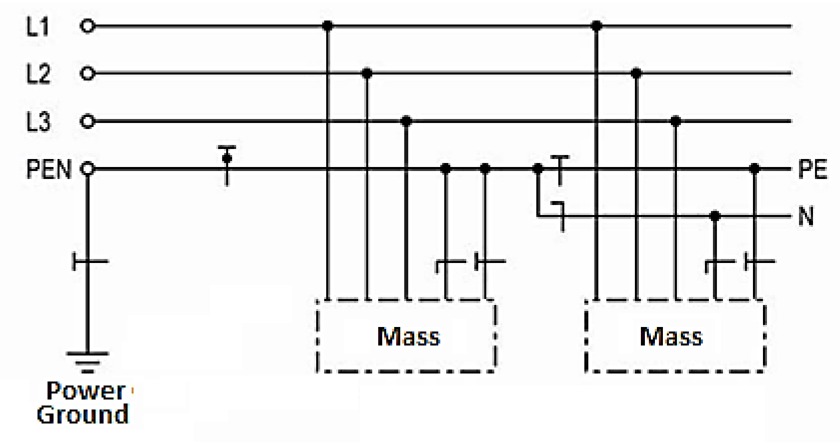

Figure 1. TN-CS scheme

Source: NBR 5410 - Item 4.2.2.2.1

It is possible to observe that the PEN conductor symbology is different from other symbology. This conductor serves as grounding and as neutral until it is divided into neutral (N) and protection (PE) conductors. In the installation performed by the author was used the present grounding scheme.

2.2 Manaus City Electric Power System

The Electric Power System (SEP) "is a system that connects energy producers and energy consumers to suppress yours demands by transmitting that energy through transmission and distribution lines, raising and lowering voltage levels through of power substations and transformers" [7].

To delimit the subject, this article will focus on distribution, more specifically, by analyzing the Amazonas Energia Distribution Networks Procedures Manual [10], this manual aims to establish criteria and procedures for urban air distribution projects, highlighting the basic criteria for sizing, protection and installation pertinent to medium and low voltage networks.

In Item 8.1.1, it is stated that in the low voltage distribution network the neutral must be multi-grounded. This feature ensures quality grounding of the power supply. As previously seen, the neutral can be grounded or not in the power supply, however in Manaus city the neutral is multi-grounded, ensuring low resistance value, besides promoting equipotentialization of the System.

In Item 8.3, line 'a' we have the grounding requirement of neutral at every 200 meters, and according addendum of this manual [11], there is a prescription of the use of 3 to 9 rods of 5/8" with 2.4meters.

2.3 PEN Conductor

The use of multi-grounded neutral makes the TN-CS scheme very suitable for use. In item 5.1.2.2.4.2 of NBR 5410, sub-paragraph 'b' we have the recommendation to grounding of the protection conductor as many times is necessary, fulfilling the role of "multiple grounding" [4]. In the case under study the protection conductor is in conjunction with the neutral, so this recommendation also applies to it. In the following paragraph we have a requirement directed to the PEN conductor, which vetoes its use for electronic equipment interconnected or shared by signal lines based on metallic cables; also, is required equipotentialization with the building if it has another grounding system or if it has a lightning protection system[5]. Such requirement can be obtained in item 5.4.3.6 of the referred standard [4].

Another important requirement is found in 6.4.3.4.1 [4], which establishes the minimum section for PEN conductors, where for copper conductors is 10 mm² and for aluminum conductors is 16 mm². For the dimensioning of the PEN conductor section we must use the later item, where there is a requirement that the conductor insulation be compatible with the maximum voltage it can withstand. Therefore, for the implementation of this article was not allowed a neutral conductor, which would become PEN, with smaller section than the required in norm.

The item 6.4.3.4.3 of this norm prohibits the connection of neutral and protection conductor after it has been separated, as can be seen in Figure 1. The following item emphasizes that this separation must be performed in distinct bars [4].

The use of the neutral conductor as a PEN conductor, in the absence of grounding in a low voltage electrical installation in Manaus has safe and protection, where according to the city's SEP has the multi-grounded neutral, fulfilling the normative requirements regarding the PEN conductor. Can be stated that the Neutral, in such condition, has resistance equivalent to that required by the PEN conductor in item 7.3.3 [4].

In line 'e' of item 5.1.2.2.4.2, we have the requirement of an overcurrent protection device (Thermomagnetic Circuit Breaker) and a differential-residual current protection device (Residual Differential Switch, IDR or DR). Regarding the DR, in sub-paragraph 'f' we have two hypotheses for its installation. In the first hypothesis (Note 1) we have the use of DR as a divider element, where the protection conductor passes outside the DR and the neutral conductor passes inside it. The splitting occurs by means of the DR, and after that, reconnection of separate conductors is not allowed, as has already been explained. In the second (Note 2) we have the PEN conductor as Neutral and the independent protection conductor, with resistance compatible to DR (similar to the TT scheme) [4].

In Annex G of the NBR 5410 [4], we have Figure G.1, which corresponds to the hypothetical equipotentialization of the TN and TT scheme. Figure 2 shows the image corresponding to the TN scheme.

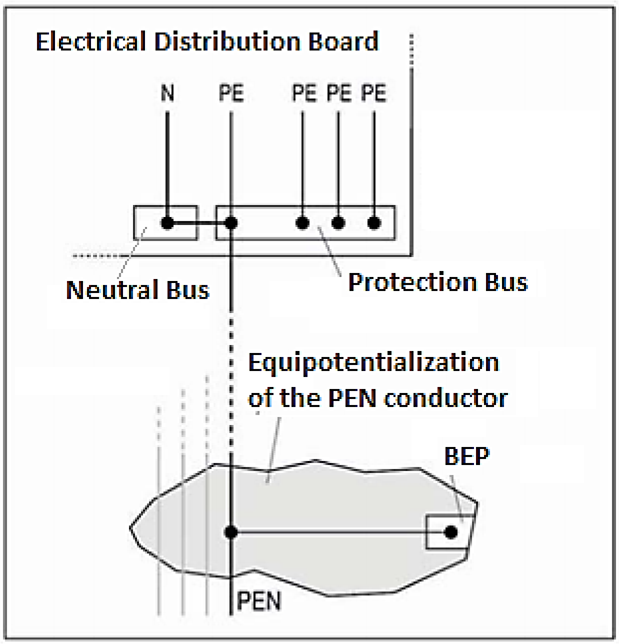

Figure 2. Hypothetical derivation of the PEN conductor.

Source: NBR 5410 - Annex G1 - Image G.1

2.4 Residual Differential Switch (IDR or DR)

In item 6.3.6.2 [4] there are parameters to be considered in the act of assimilating the DR with the Breaker. These parameters inform about the requirements of the IDR, where it must withstand overcurrent and short circuit current, especially in the absence of the circuit breaker. In summary, the rated current of the DR must be equal to or greater than the rated current of the upstream circuit breaker.

Such observation ensures that the DR will not be damaged in the presence of a short circuit or overheating. Next you can observe the principle of internal operation of the DR.

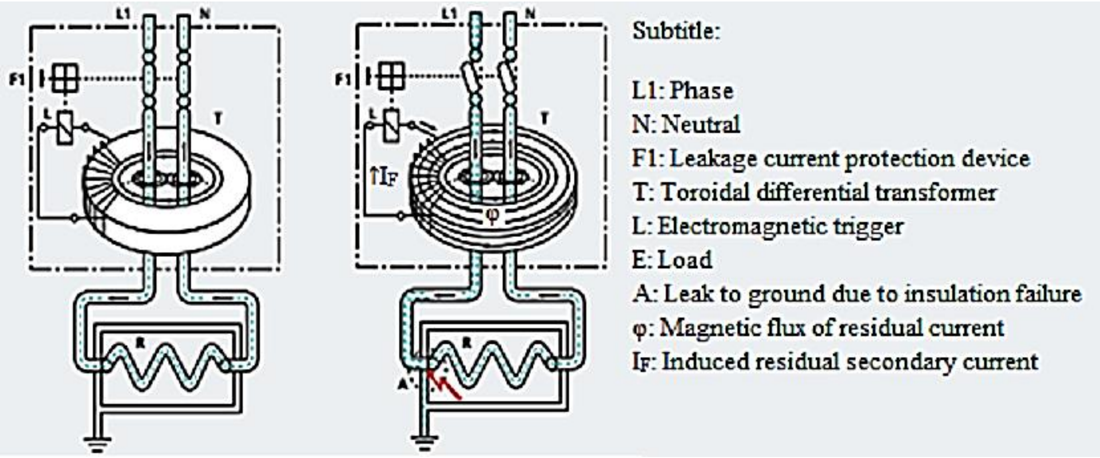

Figure 3. Internal Scheme of a Bipolar DR

Source: Siemens Catalog - DR Devices - 2017 - <www.siemens.com.br/protecao>

In Figure 3 it is possible to analyze the internal principle of the Residual Differential Breaker, where the rectangle written with dash and dot represents the IDR and the Resistor would represent the installed load. There are two inputs at the top: L1 and N, representing a phase and Neutral, standard inputs for a bipolar DR, below, we have an electromagnetic trigger that detects leakage current by magnetic induction principle. The Faraday-Lenz law or electromagnetic induction law postulates that the variation of magnetic flux on a surface induces current in a conductor, which is called induced electromotive force. The reverse is also valid, this being the basic principle of the induction motor, where an alternating current applied to the stator, promotes the movement of the rotor. In the toroidal transformer, the principle resembles, where we have the electromagnetic trigger (L), which is activated when there is a variation of the flux in the ferromagnetic core toroid. [18]

Alternating electric current passes through the toroidal core, feeds the load and returns to the core; if the current that fed the load returns without deviation, it will have the same intensity and therefore we will not have magnetic induction; however, if there is a deviation in the current that is feeding the load, regardless of the direction, this deviation will induce a variable magnetic flux, which in turn will promote an electromagnetic flux in the winding coupled with the trigger, triggering the DR.

Since it is an alternating current, this principle should be understood as a vector sum, where it is approximately zero when there is no deviation; if a deviation occurs, the vector sum becomes nonzero. The amplitude of this difference is directly proportional to the induced current in the secondary winding that powers the trigger; The trigger has a set value from 30 mA (Human's minimum sensitivity to electric shock). As already stated in the standard, DR protects against direct and indirect shock, and is required to be used. In summary, the IDR is triggered in the following cases:

- Contact of the Phase or Neutral Downstream Conductor with the protection conductor;
- Contact of the Phase Downstream conductor with Neutral Upstream conductor;
- Contact of the Neutral Downstream conductor with Phase Upstream conductor;
- Contact of the Phase or Neutral Downstream Conductor with structure grounded in getaway.

The "structure grounded" can be either a grounded carcass, as well as a person or animal which is not isolated. It is notorious that the DR does not protect against shock of phase and neutral downstream, because the current flowing through the conductor returns by the other.

3. Methodology

3.1 Study site and hypothesis construction

The implementation of this system took place through a service carried out through the company DL Reformas e Construções, where the author worked in the management of the reform under supervision of the Technical Responsible for the execution. The renovation was carried out in the Residential Condominium Manaus Park, located in the Nossa Senhora das Gracas neighborhood, in the municipality of Manaus-AM.

The building had a structural type Lightning Protection System (SPDA), so that the structures of the beams, pillars and counter beams all were grounded. The possibility of a structural grounding was considered, however, given that the apartment was on the 4th floor, the suggestion was ignored as this would result in a high resistance of grounded.

Given the impossibility of making a grounding system by rods, and the impossibility of connection of protection conductor in the bar of equipotentialization, it was thought of the implementation of the TN-C-S scheme through the method presented in this article.

3.2 Study Overview

There are many risks from lightning in a building [12]. Through NBR 5419: 2005 [5] it is possible to verify several requirements that seek to mitigate such risks. To this end, the author points out a series of procedures that ensure the viability of a structural grounding and by means of IEC 62305-4 he informs about the risks concerning electronic and electrical equipment. The most noticeable advantage in structural grounding is the possibility of equipotentialization, so it is possible to make this grounding in an apartment, however the apartment "(...) is not fully protected, neither against the unwanted effects of lightning on the structure, nor against damage to electronic equipment (...)" [12]. Regarding the application of grounding in a health facility, the normative prohibition on the use of the TNC scheme was found, where its use is criticized for being incompatible with the IDR and for not presenting safety for fault current, voltage harmonics and phase unbalance [13]. Such arguments are useful to distinguish the TNCS and TNC scheme, where the former allows the use of residual protection devices, thus depending on the location of its installation, will be protected against certain anomalies. Through ABRACOPEL's statistical survey concerning the years 2015 and 2016, a study was conducted on the effect of not using a residual protection device, resulting in the significant number of deaths due to the pathophysiological effect of shock [14]. In addition to the statistics of this yearbook, the normative obligation regarding the use of DR was emphasized. It is noteworthy that the DR should not be used in the TNC system, since as the Neutral conductor and the protection conductor can be summed up in one, the reference point is equivalent between Neutral and Protection, therefore in the possibility of a current deviation the DR would not detect. However, given the mandatory use of DR, implementation in this article does not become expensive to use. As for the design of low voltage electrical installation for buildings, a study was conducted showing the importance of complying with standards [15], with the NBR 5410 as fundamental. It is also informed about the residual differential protection device and the electrical surge protection device, where its normative obligations are described and how they should be installed according to the standard.

Through the NBR 5410 was ratified the importance of normative observation, to ensure a standard in residential electrical installation and add safety [16]. The author seeks to describe the grounding systems and detail each protection device. This document has the peculiarity of not only stressing safety, but of establishing the importance of a standard in the installation, bringing the design focus to the standard requirements.

On the importance of safety in the exercise and application of electricity, the author proposes a bibliographic research [17], having as major contribution the distinction of the main changes of NR10 (2004) [6]. The relevance of this document applies to the purpose of the paper to propose a safe method for implementing the TN-C-S scheme.

4. Analysis and Discussion of Results

As already mentioned, this article aims to justify the proposal to implement a grounding system based on the TN-CS scheme, which is suitable for the city of Manaus.

One of the problems of the implementation of this scheme is the grounding quality of the Neutral, since as seen in Figure 1, the PEN conductor is grounded in the power supply, fulfilling the role of Neutral and Protection conductor, so its resistance must be such that meet as a protection conductor. Based on this, the Neutral conductor cannot simply be used as a PEN conductor because the required resistance of the neutral conductor is different from the resistance required for the Protection conductor.

To ensure system security, the Tetrapolar IDR was used immediately after the General Thermomagnetic Circuit Breaker. The connection between these and how the TNCS scheme was implemented can be seen in Figure 4:

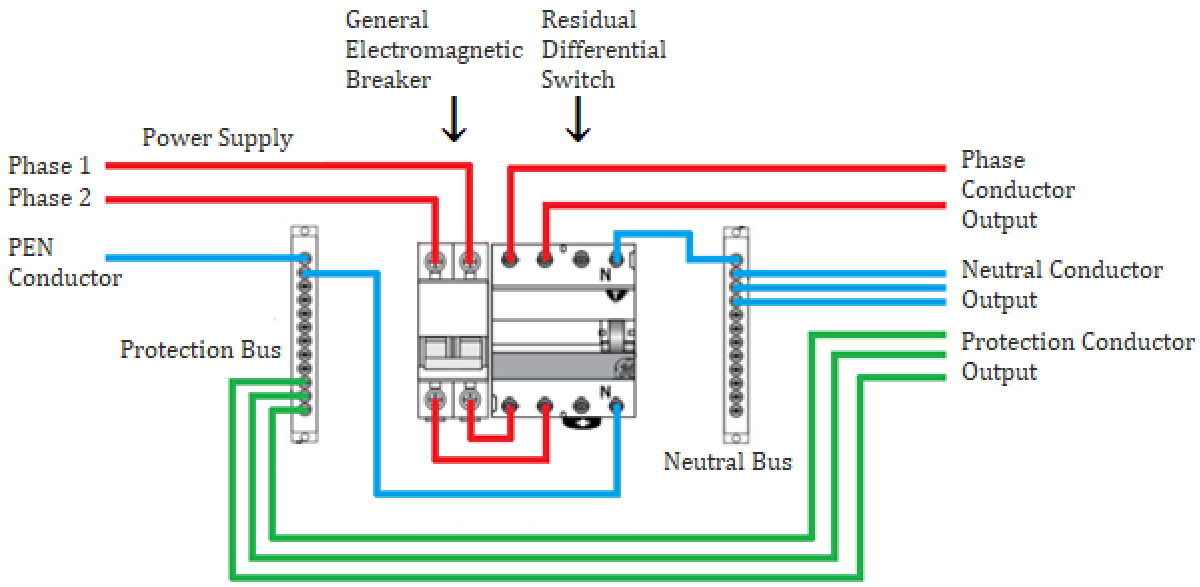

Figure 4. Breaker Arrangement and DR for TN-CS Schema Implementation

In Figure 4, we have the blue PEN conductor, denoting that it previously played the role of Neutral conductor. From this, the PEN conductor was connected directly to the Protection bus, fulfilling the requirement of NBR 5410 [4], where it says that such conductor should pass outside the DR, as previously described.

From the Protection Bus, the PEN conductor was directed to the input of DR. Such connection represents the branch point seen in figure 1, where the PEN conductor is divided into Neutral and Protection.

In the hypothetical situation of not using the DR, we would have a very serious problem, because the PEN conductor would be directed to the protection bus and then to the neutral. So, in the hypothetical situation of a PEN conductor break, we would not have a short circuit, and since the neutral and protection bus are connected, all grounded ground would be energized and could easily cause an electric shock to a person who not isolated.

Another problem that should be avoided is the grounding of neutral after the DR, this would cause the protection conductor and Neutral conductor to be associated again, making them similar to the PEN conductor at the input. The problem that occurs is the non-tripping of the DR in situation of contact of the phase and neutral upstream and downstream, or downstream and upstream, likewise with the contact of phase and protection conductor.

This error could result in the death of a person if they are not isolated when having direct or indirect contact with a charged conductor. therefore, this connection is prohibited.

Regarding the quality of the neutral conductor that would become the PEN conductor, the Manaus distribution system promotes the multi-grounded neutral, which is suitable for this implementation. The Neutral conductor section is an only limitation for this implementation and can make it costly as it should be at least 10 mm^2.

5. Conclusion

The present article addressed the method applied by the author to solve the demand for a protection conductor in a building that did not have it. To apply this method, it was necessary a normative technical support that guaranteed quality in service and customer satisfaction. In the search for this support, the idealization of this article was started.

Therefore, in addition to a method, it is possible to obtain from this article a normative mapping regarding the subject in question, where each statement was justified by norms and scientific principles.

The conclusion that the developed method meets the requirements required by norm, cooperated to validate the importance of this article for low voltage installations in Manaus.

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