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Risk management during construction of electric power substations

Gerenciamento de riscos durante a construção de subestações de energia elétrica

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Abstract: The construction of electric power substations poses a great number of risks due to its dangerous environment. The objective of this work was to evaluate the perception of construction workers on risks, methods they use for evaluation and managing risks to which they are exposed. This study carried out a qualitative and quantitative analysis during the expansion of one electric substation, adding an additional 100 MVA power transformer. The risks were identified and analysed by using the Preliminary Risk Analysis (PRA). Additionally, a questionnaire on construction safety was created and applied on all 27 workers which participated in the construction. The results showed which activities are present during the construction of a power substation, which risks are involved and how to manage them. It was found that among several, the PRA and Checklists were the most commonly used analysis tools. Further on, it was found a relation between training and risk perception. Among perceived risks were: noise, working at heights, electric shocks, traffic accidents, poisonous animals, dust, fire and explosions. The conclusion of this study was that the construction of electric power substations brings several safety risks and that the instruction of workers allows an effective risk management, and can reduce the number of accidents in this type of working activity.

Keywords: Work safety; Civil construction; Electrical energy substation transmission; Electrical energy; Occupational risks evaluation.

Resumo: *A construção de subestações de energia elétrica representa um grande número de riscos devido ao seu ambiente periculoso. O objetivo deste trabalho foi avaliar a percepção dos trabalhadores da construção civil sobre os riscos, os métodos que utilizam para avaliação e o gerenciamento dos riscos a que estão expostos. Este estudo realizou uma analise qualitativa e quantitativa durante a expansão de uma subestação de energia elétrica, adicionando um transformador de potência de 100 MVA. Os riscos foram identificados e analisados utilizando a Análise de Risco Preliminar (APR). Além disso, um questionário sobre segurança na construção foi criado e aplicado em todos os 27 trabalhadores que participaram da construção. Os resultados mostraram quais atividades estão presentes durante a construção de uma subestação de energia, que os riscos envolvem e como gerenciá-los. Verificou-se que entre várias, as APR e Checklists eram as ferramentas de análise mais utilizadas. Mais adiante, foi encontrada uma relação entre treinamento e percepção de risco. Entre os riscos percebidos estavam: ruído, trabalho em alturas, choques elétricos, acidentes de trânsito, animais peçonhentos, poeira, incêndio e explosões. A conclusão deste estudo foi que a construção de subestações de energia elétrica traz diversos riscos de segurança e que a instrução dos trabalhadores permite um gerenciamento eficaz dos riscos, podendo diminuir o número de acidentes nesse tipo de obra.*

Palavras-chave: *Segurança do trabalho; Construção civil; Subestação de transmissão de energia elétrica; Energia elétrica; Avaliação de riscos ocupacionais.*

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1 Introduction

The demand for electricity has a global growing trend. In Brazil, despite recession, it has been growing during the last years. Future prospects for the evolution of electricity consumption depend on some assumptions and possible macroeconomic scenarios. In order to serve consumers with supply and quality, some investments are required to improve its infrastructure works in the generation and transmission sectors. According to the Brazilian Energetic Research Company (EPE, 2017), the prediction of electrical consumption for residential, industrial and commercial customers in Brazil is that it should increase from ≈450 GWh in 2016 to ≈700 GWh in 2026. The Brazilian government estimates 39 billion BRL (≈0.42 billion USD) to be invested in construction of transmission sectors in the period between 2015 and 2018. Most of the companies responsible for the construction are still to be hired, while currently under contract there are already around 22 billion BRL (≈6.94 billion USD) (Brasil, 2015).

In the transmission sector, the construction works for new substations and transmission lines, or expansion of existing facilities, are generally authorized by the Brazilian National Electric Energy Agency (Agência Nacional de Energia Elétrica - ANEEL), through transmission auctions under a concession regime, authorizing resolutions or permission contracts. The construction sector involves a high number of workers which are involved in building electrical substations. As the civil construction implements new technologies (automation, telecontrol, telesupervision and computerization), there is a significant change in work organization, including outsourcing, adding cooperatives and voluntary redundancy plans. These changes have brought significant harm to workers, as it resulted in increased unemployment and a lack of health and safety conditions. Consequently, the construction industry suffered an increase in the number of work-related accidents involving the electric risk (Miranda & Sica, 2017), which is just one of many risks present during the construction, expansion and renovation of Eletric Power Transmission Substations.

The construction work on electric power transmission substations includes electrical energy related risks, in addition to physical, chemical, ergonomic, and commonly presents construction-related risks. According to Barkokébas (2014), 28% of accidents in construction were related to falls, 17% to falls from height, and 2.8% to electrical shocks. However, these 2.8% represented 50% of fatal cases. For Roberts (2016), electricity is an omnipresent risk; it must be managed differently than any other type of risk. Work on expansions or nearby services around powered installations is conducted in presence of high voltage electricity with values ranging from 69kV to 750kV, which are fatal for humans. In this work scenario, electrical accidents can easily occur, representing significant causes of occupational fatalities in the world (Koustellis et al., 2013).

In Brazil in 2016, compared to the previous year, there was an increase of work-related accidents and illnesses, costing the National Institute of Social Security (INSS, 2017) an additional 4.2 billion BRL (≈1.33 billion USD). In order to avoid accidents, the risk analysis has been widely used in different sectors.

An individual method may not achieve the optimal risk assessment results for workplaces (Marhavilas et al., 2013). It is possible to associate several analysis tools, which aim to facilitate the study and direct to appropriate control actions. According to legal requirements, the Occupational Health and Safety Management guidelines, as a part of the quality system, oblige the employer to promote health and integrity to workers, including phases from implementation to maintenance of systems.

Nevertheless, although there are legal requirements, developed safety-management tools and techniques, the work-related accidents and illnesses continued to grow. Future trends show that electrical requirements will continue to grow, creating a need to build new power stations, and therefore remaining a high risk for those building them. There is an urgent need to improve safety conditions in construction of electrical energy transmission substations in order to improve the safety and health of workers involved. The objective of this work was to evaluate the perception of construction workers on risks to which they are exposed, investigate on which methods they use to evaluate and manage those risks. Further on, the objective was to discuss and compare these results with currently available data on work-related accidents and illnesses, finally to give suggestions for improving occupational safety and health.

2 Bibliografic review

The bibliographic review was conducted in order to review current knowledge and information on construction work safety in the electrical sector. The review was conducted on statistical data of accidents from construction in the electrical sector (FUNCOGE, 2018; INSS, 2018) and the Brazilian regulatory norms. Additionally, the review was conducted in 8 databases: Academic Search Complete; Cite Seer; Library Information Science and Technology Abstracts, Scopus, Web of Science; IEEE explore; Science Direct; and PubMed/Medline. For searching purposes, keywords and expressions were used: “construction”; “substations”; “transmission”; “risks”;

"accident prevention"; "techniques for risk analysis"; "occupational risks"; "safety in electric installations"; which resulted in 11 articles.

2.1 Global data on work accidents in the electrical sector

In the United States in 2016, out of 4,693 work-related fatalities in private industries, a number of 991 (21.1%) were in construction. The leading causes of deaths (excluding traffic-related deaths) in the construction industry were due to falls (38.7%), followed by struck by an object (9.4%), electrocution (8.3%), and caught-in between (7.3%) (OSHA, 2018).

In Great Britain in 2017, fatal injuries in the construction industry represented 30% of all work-related fatal injuries, with electrocution representing 8% of all causes (Edwards, 2017).

According to the International Electrical Safety Foundation, the highest rate of electrocution occurs among construction contractors. In the United States, the Agency of Labour Statistics registered electricity as the major cause of death between 2003 and 2011 with a record of 40% of cases (Zhao et al., 2016).

Nevertheless, although the construction industry is responsible for a high number of fatal accidents, it is important to consider that it also employs a high number of workers. According to the annual average from 2012 to 2017, in terms of the number of fatalities per 100,000 workers employed, the rate of fatal injuries in the construction industry was 1.82, while for the agricultural industry 8.44, and the waste and recycling industry with 6.80.

2.2 Brazilian data on work accidents in the Electrical Sector

Brazilian data on work accidents are registered in documents issued by companies. The document is based on the procedure for preparation of the Work Accident Communication (Comunicação de Acidente de Trabalho - CAT) and it consider both work-accidents and occupational diseases. The rules are specified by the norm NBR 14280 (ABNT, 2001), establishing criteria for registration, communication, statistics, investigation and analysis of occupational accidents, its causes and consequences.

There are two main registries related to the Brazilian Electrical Sector on work accidents considering phases of generation, transmission and distribution of electrical energy. These are: the Statistical Yearbook of Labour Accidents (Anuário Estatístico de Acidentes de Trabalho - AEAT), prepared by the Ministry of Labour and Employment (Ministério do Trabalho e Emprego - MTE); and the Statistics Report for Accidents in the Brazilian electric sector, prepared by the Management Committee Foundation (Fundação Comitê de Gestão Empresarial - FUNCOGE).

2.2.1 The statistical yearbook of labour accidents

The statistics of occupational accidents can be presented according to some criteria, such as the International Classification of Diseases (ICD) and the Brazilian National Classification for Economic Activity (Classificação Nacional de Atividade Econômica - CNAE). The National Classification for Economic Activity is a standard officially adopted by the National Statistical System. However, there is not a specific code for economic activity of an electric energy substation (Subestação de Energia - SE). The construction of an Electric Energy Substation involves several activities, each having its National Classification code.

For example, the National Classification code 4321 represents accidents in the electrical sector (illustrated in Figure 1). On that figure it was observed that some accidents were registered (Typical, Communication, Work Sickness), while others were not ("sem cat" or Without Work Accident Communication). The accidents were separated by type: work sickness; commuting; and typical accidents. Between 2014 and 2016, it was recorded a slight decline, but still showing high values. Through 2016, the accidents in the electrical sector occurred on daily bases, emphasizing the need for actions to minimize them.

Figure 2 shows the data of the Brazilian Association for the Awareness of the Dangers of Electricity (ABRACOPEL, 2018) in relation to the number of fatal and non-fatal accidents caused by electrocution in Brazil during the years from 2003 to 2017.

Compared with the number of non-fatal accidents in Brazil during the past years, there is an increase during the year 2016 and 2017. As it could be noted from the Figure 2, the number of registered fatal accidents is much higher than the number of non-fatal accidents. This could be explained with a high number of not recorded non-fatal accidents, while all fatal tend to be recorded.

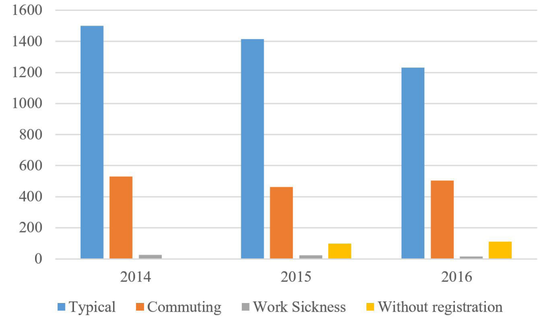

Figure 1. Work Accidents in the electrical sector. Adapted from Instituto Nacional de Seguridade Social (INSS, 2018).

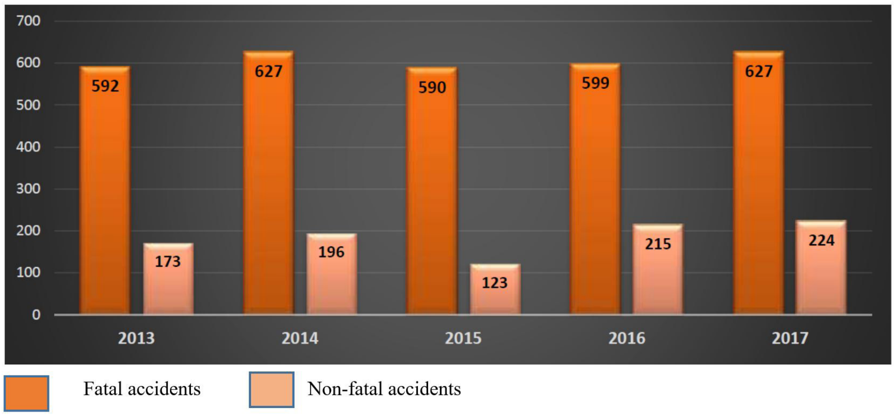

Figure 2. Total number of accidents of electrical origin in Brazil from 2013 to 2017. Adapted from ABRACOPEL (2018).

Figure 3. Number of fatal accidents in the electricity sector for contracting and outsourced companies in the period from 2004 to 2016. Adapted from Fundação Comitê de Gestão Empresarial (FUNCOGE, 2018).

2.2.2 The statistics report for accidents in the Brazilian electric sector

The Management Committee Foundation has been releasing reports since 1977. The reports serve as a management tool for companies from the electrical sector. The Figure 3 illustrates the numbers of typical fatal accidents which occurred in the Brazilian Electrical Sector from 2004 to 2016, between electricity generation and transmission companies. During this period, the electric sector was a sector with a high number of fatal accidents.

The Figure 3 illustrates the data of Funcoge on the number of fatal accidents in the electricity sector for contracting and outsourced companies in the period from 2004 to 2016. The vertical axis represents the number of fatal injuries, while the horizontal axis represents the years in which the fatal accidents occurred.

The number of accidents in outsourced companies has been decreasing over the years, decreasing from 74 in 2006 to 16 in 2016. Nevertheless, the number of fatal accidents in outsourced companies is still high in comparison with contracting companies.

2.3 Electrical substations

The Electrical Energy Substation is an installation composed of a set of equipment used to control, modify, command, distribute and direct the electric power flow in an electric system. It has one or more of the following functions: Manoeuvring, which allows connecting and disconnecting electrical equipment; Transformation, which allows increasing or decreasing the voltage levels according to the electrical system operation; and Distribution, which allows the power flow subdivision to meet different feeders.

The network substation in the Brazilian electric transmission system is with voltage levels of 230 kV (ANEEL, 2017). The activities in this work environment, in addition to all possible risks present in the construction industry, include also risks related to high voltage electricity, where any mishandling can be fatal. During the development of construction services, it is necessary to include professionals from different areas, in order to ensure safety. The tasks of construction include building bases for different equipment, installing current transformers or potential transformers, disconnecting switches and circuit breakers, fire wall construction, electromechanical equipment and setting up of high voltage buses, setting-up and cabling of de-energized and powered panels.

2.4 Risks management and evaluation systems

There are several national and international laws regarding this issue. The Occupational Health and Safety Assessment Series (OHSAS 18.001) represent an international standard which establishes requirements related to occupational health and safety management. It is expected to be replaced by ISO 45001 (BSI, 2017), a new publication from the International Organization for Standardization. The aim of risk management is to eliminate risks, and when it is not possible, to minimize them. According to the study analysing data from the International Labour Organization (ILO), 96% of accidents could be avoided by analysing incidents or probable incidents (Barkokébas, 2014).

In France, the International Conference on Large High Voltage Electric Systems (CIGRE) suggested the creation of a working group for 2017 with the proposal to investigate on experiences of companies from the electrical sector in relation with risk management in substations. One of the main objectives is to promote safety in several stages of an enterprise: construction; operation; and maintenance during the installation (CIGRE, 2014).

2.5 Risk analysis techniques

There are several techniques for Risk Analysis: "Failure Mode and Effect Analysis" (Análise de Modo de Falha e Efeito - AMFE); Fault Tree Analysis (Análise de Árvore de Falha - AAF); "What if?", which indicates possible risks; "Checklists" (used in daily activities based on certain parameters); "Hazard and Operation-ability Identification Studies (HAZOP)"; and the "Preliminary Risk Analysis (APR)" (Cardella, 2013).

3 Case study

A quantitative and qualitative study was conducted on an Electric Power Substation located in Recife, Pernambuco, Brazil. The type of facility was the Air Isolated Substation (AIS), with capacity of 300 MVA. The construction works contemplate the expansion of a new transformer section, together with associated equipments, in order to increase the transmission capacity.

According to the "Consolidation plan for transmission works" (Brasil, 2015), it was decided to expand the facility in order to increase the transmission capacity of electric power for additional 100 MVA. The National Agency for Electrical Energy (ANNEL) authorized the implementation of the fourth three-phase power transformer of 230/69kV, 100MVA, to be installed alongside other existing and powered electrical equipments with voltage levels of 69kV and 230kV. The electric Substation is provided with access roads and buildings which serve as a base, like the control house which houses the operators, allocates protection panels and the equipment panels.

3.1 Construction process and activities

The construction process (illustrated in Figure 4) could be divided into several working activities: a) cable-ducts excavations; b) concreting the bases; c) construction of oil containment basin; d) fire-wall construction; and e) grounding through the exothermic welding process.

a) The cable-ducts are required to accommodate all wiring needed to interconnect the courtyard to their respective protection and control panels which are located in control rooms and relay huts. Excavations (illustrated in Figure 4a) could be handled manually by using conventional tools (with shovels, picks, diggers and jackhammers) or mechanically (with backhoe loaders);

b) Concreting the bases is required to cover and protect the cable installation after finalizing the base frame activities. Concreting (illustrated in Figures 4b1, 4b2 and 4c) could be handled manually using the wheelbarrow, or it could be supplied directly from the concrete mixer truck;

c) Construction of oil containment basin are required to contain the transformer insulating liquid from a possible leaking, avoiding soil and groundwater contamination, and in case of fire, not to reach parts of the substation. It is required by the Brazilian Standard Norm NBR 13231 (ABNT, 2015), dealing with fire protection in Electrical Substations and by environmental legislation and fire departments. The basin (illustrated in Figure 4d) is interconnected through the structure (separator container), allowing the separation of water from the oil. In this venture, the oil separator container was already built, and it was part of the construction site. There was an interconnection between the new containment basins, the new

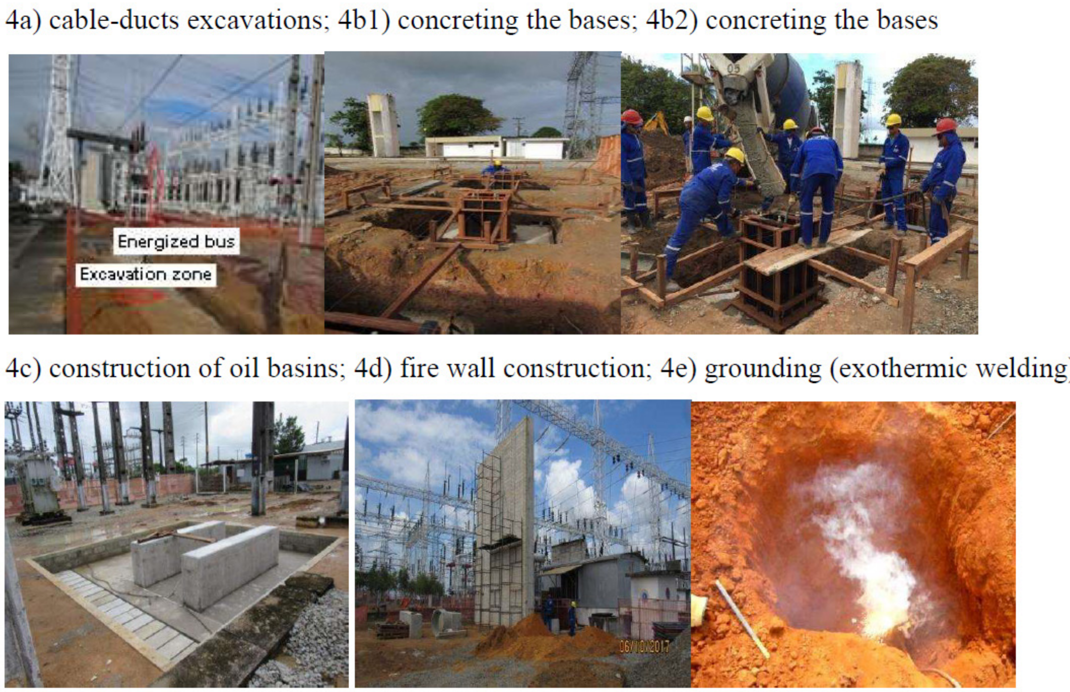

Figure 4. The construction activities.

transformer and the reactor with the existing oil separator container;

d) Fire-wall construction is required to act as a barrier in case of fire and explosions in any electrical transformer, containing the fire from spreading to other units. The structure (illustrated in Figure 4e) is made from pre-moulded concrete slabs covered with anti-thermal material, needed to be higher that the transformer, reaching altitudes higher than 10 meters;

e) Grounding through the exothermic welding process should be done with special care concerning the soil loop at an electrical energized substation. The workers will find the existing ground during excavation services, which in normal conditions, shouldn´t present a risk to the workers. Nevertheless, in case of a short circuit, high currents could circulate, and pose risks of accidents.

3.2 Participants

As explained through the previous chapter, the construction process involved various activities. The activities were carried-out by professionals from different areas of expertise, from carpenters and masons to technicians and engineers. In total, 27 workers participated in the interview survey: civil engineers (3); electrical engineers (1); safety engineers (2); safety technicians (5); electrical technicians (1); construction technicians (1); workers performing iron and concrete services (1); carpenters (2); civil workers (1); backhoe operators (1); masons (4); jackhammer workers (1); assistant mason (1); assistant electrician (1); general assistant (2); construction assistants (2). From interviewed participants, 17 were full-time workers of the Electrical Substation (belonging to the hired company), while 10 were employees of the contracting company.

3.3 Methods

For analysing risks, this study used the technique of Preliminary Risk Analysis. This technique allows analysing risks in a conscious and anticipated way, allow the evaluation of events with higher danger and risks (Tavares, 2012), and identify their causes and consequences, finally to be able to establish planned control measures.

For the purpose of the study, a questionnaire was elaborated. The questions were based on literature dealing with environmental and accident risks, risk analysis tools, controlling measures and trainings useful for these types of operations. It included 21 questions in relation to the workers identification, profession, health history, the trainings they passed, how they plan and organize their work, risks to which they are exposed, equipment and safety measures they use, and general satisfaction on their work safety.

The questionnaire evaluated workers' perceptions regarding occupational hazards, awareness on safety issues and risks involved during the development of their activities, workers' adoption of risk analysis tools and control measures. Additionally, conducted activities were photographically recorded for risks identification and mappings, and to be used in further data analysis.

3.4 Data analysis

All gathered data were analysed by using the Excel statistical tool-box, evaluating risks perception among workers, making it possible to compare acquired data with previously conducted studies.

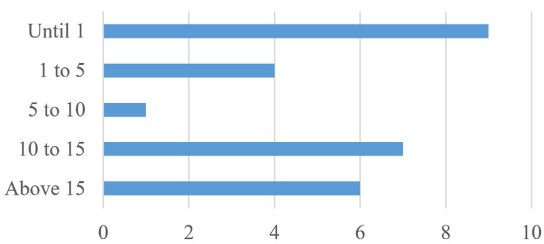

Figure 5. Distribution of interviewed workers by work experience in years.

4 Results

The results from the questionnaire survey were illustrated in the following figures. Workers perform activities in the open air, which is called the patio of energized equipment (where the presented risks are highly present) and in offices - those working in planning and inspection activities.

The Figure 5 illustrates the workers by their work experience (from 0 to 10 years). As it could be noted, 5 (19.2%) had more than 15 years of experience, 7 (26.9%) had between 10 and 15 years, 1 (3.8%) had between 5 and 10 years, 4 (15.4%) between 1 and 5 years, while 9 (34.6%) had less than 1 year of experience. Figure 6 shows that 14 (52%) of the interviewed workers had more than 5 years of professional experience.

As shown in Figure 5, nearly half of the workers (13/27, 48%) which participated in this project had more than 10 years of working experience.

The Figure 6 illustrates most commonly used risk analysis tools. As it could be noted, the Preliminary Risk Analysis (PRA) was used by 17 workers, the Preliminary Hazard Analysis (PHA) was used by 10, check lists were used by 16, the Manner and Effect Analysis (FMEA) by 2, other tools by 1, while no answers were recorded on using Errors Analysis (EA), and not being able to inform what is using.

The Figure 7 illustrates which occupational safety and health trainings and educations were conducted by considered workers. As it could be noted, all 27 were

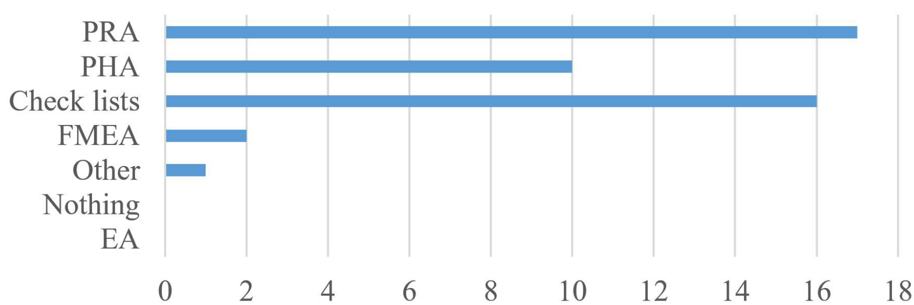

Figure 6. Usage of Risk Analysis Tools.

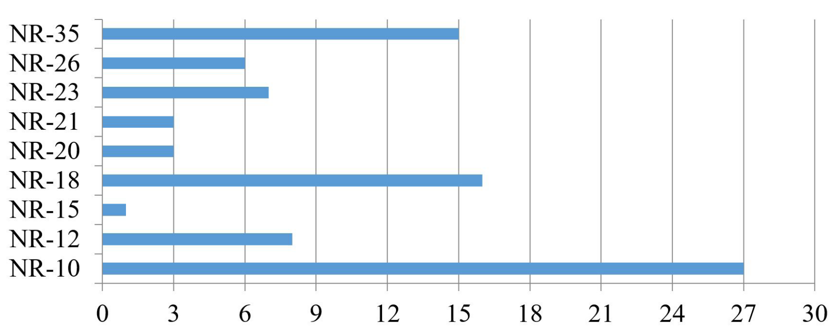

Figure 7. Number of trainings and educations by Brazilian regulatory norms. NR = Represent the Brazilian regulatory norm (Norma Regulamentadora).

trained in Electrical safety (NR 10), 16 in construction safety (NR 18), 15 for working at heights (NR 35), 8 in Safety with mechanical equipment (NR 12), 7 in Fire safety (NR 23), 6 in Safety signalization (NR 26), 3 for working with flammable and combustible materials (NR 20) and working outdoor (NR 21), and 1 for Unhealthy operations (NR 15).

The Figure 8 illustrates which personal protective equipment (PPE) was mostly used by considered workers. As it could be noted, usage of 15 different PPE's was evaluated.

The mostly used PPE was helmet (26 workers), safety boots (25), glasses (22), welding mask (21), appropriate clothing (18), hood (15), air purificator (13), hearing protection (4), facial protection (3), electrical isolation gloves (3), gloves (1), cream protection against agents (1), sleeves (1), other (1), sunscreen protective cream (0).

The Figure 9 illustrates the perception of workers on safety solutions present at the construction site. In total, one protective net was encountered, 2 safety signs, 4 safety nets, 5 fences, 16 barriers, 5 electrical parts with isolation, and 25 safety signalizations.

The Figure 10 illustrates a list of 22 occupational safety and health risks identified/perceived by workers.

Among various risks present during this construction activity, most of the workers recognized: noise (88.9%); electrical shocks (85.2%); traffic accidents (85.2%); poisonous animals (81.5%); dust (77.8%); fire and explosions (74.0%); and falls (59.3%).

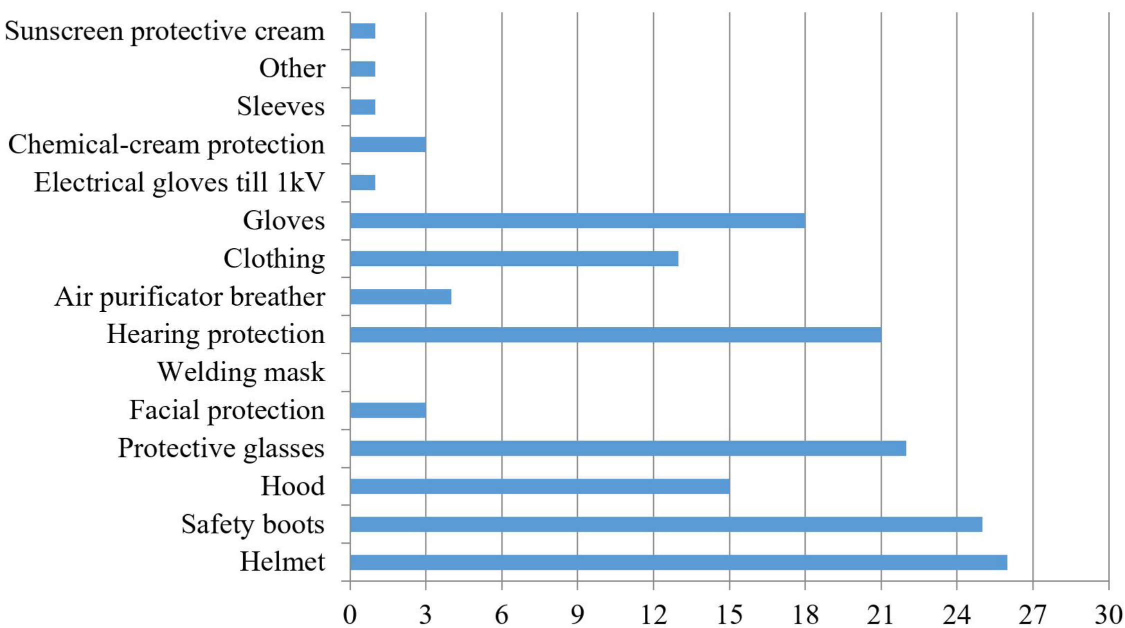

Figure 8. Personal Protective Equipment used by workers.

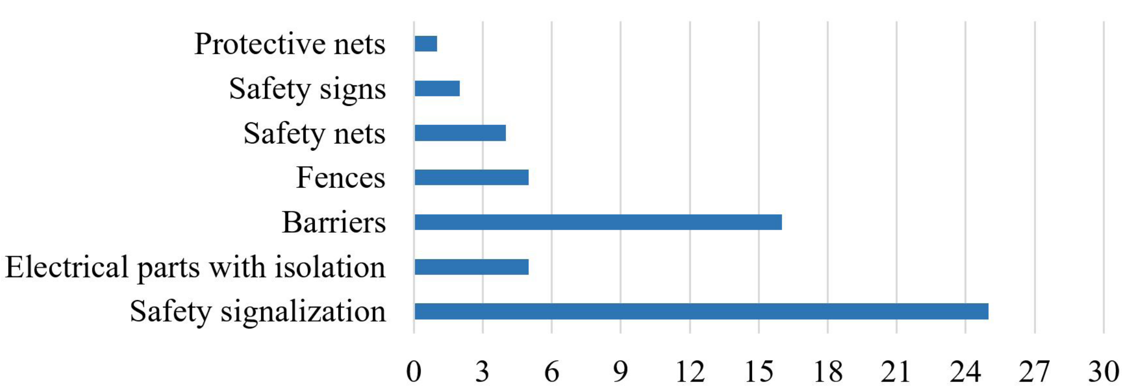

Figure 9. Perception of workers on safety solutions at the construction site.

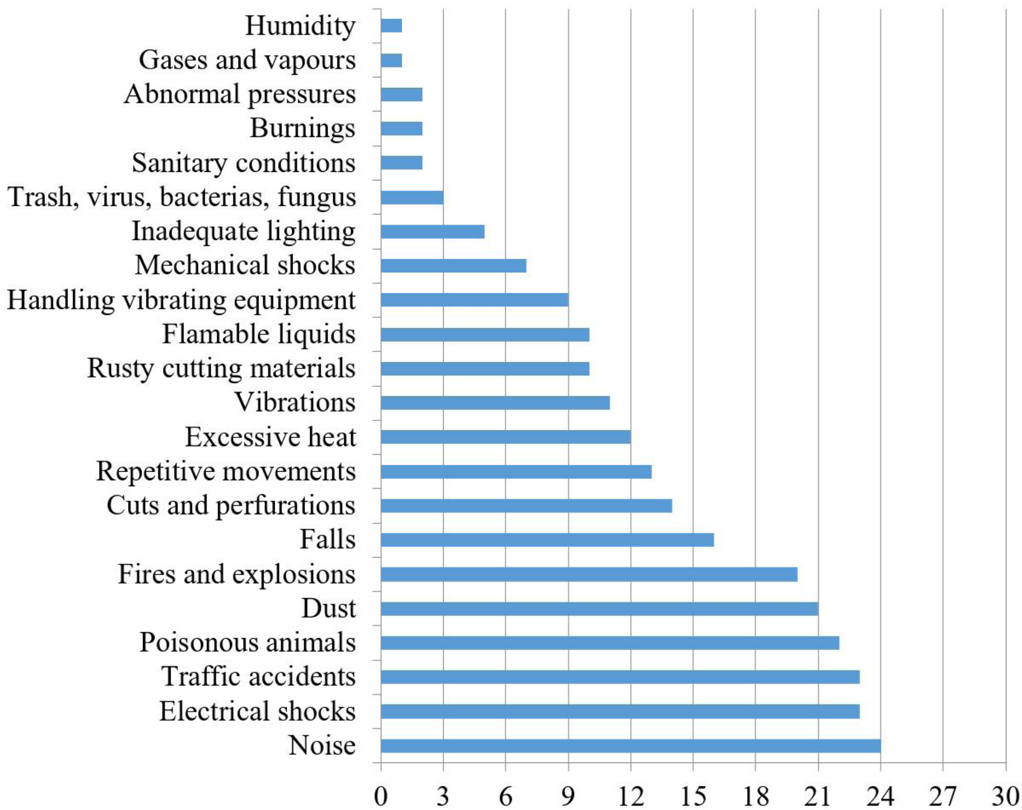

Figure 10. Identification of occupational safety and health risks.

5 Discussion

Although the construction industry usually involves a high number of risks, this type of construction involves even more. Therefore, it is necessary to adequately assess risks, for all workers to undertake trainings, to be able to perceive high risks and to protect them with adequate PPE. The workers had to perform specific trainings (as required by regulatory norms specified by the Brazilian Ministry of Labour and Employment) depending on their job description and the activity they conduct. As illustrated in Figure 7, 100% of workers carried out the training on electrical safety (NR 10). This was expected as the present construction activities were conducted in powered areas. More than 60% of employees carried out the training on construction safety (NR 18). As activities were often performed at heights above 2 meters from ground level, 55% of workers carried out the training for working at heights (NR 35). Other trainings had lower frequency of participation.

As it is illustrated in Figure 8, the most used PPE were helmets (96%) and protective boots (92%). This could be associated with mandatory requirements from the Brazilian legislation for all those present on construction sites. Approximately 30% of the interviewed employees suggested training with smaller breaks for acquiring new relevant knowledge to carry out their tasks properly, as well as requesting some workload with practical classes in the training sessions. It is common for workers to undertake compulsory training, but in addition to these, extra trainings such as lectures can promote awareness and minimize risks.

5.1 Risk analysis tools

The risk analysis tools should always lead good safety management practices (Bridi et al., 2013). Through analysing risks through the process of this type of construction, several analyses were made. The cable-ducts excavations could be done faster by using mechanical tools, nevertheless, the movement of backhoe loaders pose another type of risk, as its' spears might approach or even touch the high voltage buses. Therefore, prior to any working activities it is necessary to conduct a preliminary risk assessment. Once the excavations are finalized, it is important apply adequate fall-protection measures around all holes and ditches. During the process of concreting the bases, it is necessary to use concrete vibrators to improve the concrete densification. It is important for all electrical equipment to be earthed and comply with the Brazilian Standard Norm NBR 5410 (ABNT, 2008). The construction of fire-walls requires the use of scaffoldings, for workers to be able to assist during the placement of pre-moulded slabs. As work is conducted on heights, it is necessary to carefully plan the working activity and apply fall-protection measures (Nonnenmacher et al., 2017; Peñaloza et al., 2015) . Slabs could be lifted to a desired height by using manual methods or by using the truck-crane. This activity poses great risk of electrocution due to having moving parts in the proximity of powered transformers. For grounding through the exothermic welding, several preventive measures should be applied. All elements should be previously identified and employees should not have any contact with the soil loop. In the soil loop expansion services, every new part should be made independently, leaving the interconnection with the existing part for the last phase of work. This activity carries burning risk to workers, once the exothermic solder is used to make the connections. Another risk is for worker´s hands to be squeezed or getting their faces injured when working on the grounding.

The questionnaire results on most commonly used technique for risk analysis (as illustrated in Figure 6) show that they were: the Preliminary Risk Analysis (PRA); check lists; and the Preliminary Hazard Analysis (PHA). The reasons for using PRA could be associated to the same reasons as why the authors selected it (it analyses and anticipates risks, it establish a plan through control measures). As illustrated, workers commonly used more than one risk analysis tool. The work should use risk analysis techniques and try to analyse the working activities in phases (Cambraia et al., 2008).

5.2 The relation between training, risk perception and the use of PPE

Table 1 was created in order to facilitate the discussion on data illustrated in Figure 7 on trainings which workers conducted, Figure 8 on PPE they used,

Table 1. The relation between collected data.

Groups	Nr	Undertaken trainings	Nr	Risk Perception	Nr	PPE in use
Group 1 (from 19 to 27 workers)	27	electrical safety (NR 10)	24	noise	26	helmet
			23	electrical shocks	25	safety boots
			23	traffic accidents	22	protective glasses
			22	poisonous animals	21	welding mask
			21	dust	18	appropriate clothing
			20	fires and explosions		
Group 2 (from 10 to 18 workers)	16	construction safety (NR 18)	16	falls	15	hood
	15	working at heights (NR 35)	14	cuts and perforations	13	air purificator
			13	repetitive movements		
			12	excessive heat		
			11	vibrations		
			10	rusty cutting materials		
			10	flammable liquids		
Group 3 (from 0 to 9 workers)	8	safety with mechanical equipment (NR 12)	9	handling vibrating equipment	4	hearing protection
	7	fire safety (NR 23)	7	mechanical shocks	3	facial protection
	6	safety signalization (NR 26)	5	inadequate lighting	3	electrical isolation gloves
	3	working with flammable and combustible materials (NR 20)	3	trash, virus, bacteria, fungus	1	gloves
	3	working outdoor (NR 21)	2	sanitary conditions	1	cream protection against agents
	1	unhealthy operations (NR 15)	2	burnings	1	sleeves
			2	abnormal pressures	0	sunscreen protective ream
			2	gasses and vapours		
			2	humidity		

and Figure 10 on their risk perception. As answers were gathered from 27 workers, the collected data was classified into three main groups: high number (group 1, from 19 to 27); medium number (group 2, from 10 to 18); and low number (group 3, from 1 to 9).

As it could be seen from Table 1, a high number of workers were trained on electrical safety, medium number on construction safety and working at heights, while a low number for safety with mechanical equipment, fire safety, safety signalization, working with flammable and combustible materials, working outdoor and unhealthy operations. Some risks, as for example the abnormal pressure was perceived by workers. This type of answers should be rejected from consideration as all activities were developed under normal pressure, and could be justified with workers not understanding the question or the topic.

5.2.1 Unhealthy operations

The following Figure 11 illustrates data in relation to the training of unhealthy operation (NR 15), and it compares with risk perception of each factor considered in that training (blue columns) and the percentage of workers which used PPE to protect them from each of those risks.

As it could be seen from Figure 11, percentage of workers trained for unhealthy operations were very low. In this group of risks, they were often perceived by a high number of workers, but those which could be associated with not understanding the risk (not trained). Further on, although workers perceived risks, often they didn't wear adequate PPE to protect them for those risks, which could be also associated to not being trained for it.

The risk perception of noise was high (89%), although the number of workers which used hearing protection was low (15%). Onsite, it occurs in various activities, usually caused by vehicles passing on roads nearby the area which was under construction. Further on, noise occurs when turning on diesel emergency generator which serves as the temporary facility onsite, or with operational equipments such as transformers, isolators, cement mixers, among others. Dust was perceived as risk from a high number of workers (78%), but air purificators were used moderately (48%). Dust is commonly present on constructions sites, therefore adequate PPE is necessary for preventing this agent from entering into the human respiratory system.

Excessive heat was recognized by a moderate number of workers (44%). Adequate protection through wearing hoods, sleeves and applying sunscreen protective cream was also used moderately (56%). Usually, construction activities are carried outdoor, exposing workers to high temperatures which makes the adequate clothing important. For other agents illustrated in the Figure 11, they were perceived as risks, but no PPE was applied.

Vehicles and equipment that generate high vibration, such as: compactors; breakers; backhoes; circular sawings; sanders; machines; marteletes; screwdrivers or forklifts; require adequate protection and the use of the hearing protection. Exposure to this risk should be evaluated according to limit values as specified by the regulatory norm NR 15 and according to the body region which is subject to vibration as specified by the technical norm on Hygiene Occupational Standards (Norma de Higiene Ocupacional - NHO). The PPE include anti-vibration gloves (specified by ISO 10819) and anti-vibration seats for vehicles. Another measure is to check the defective parts and to regularly schedule maintenance and ensure that machines are in good condition.

5.2.2 Electrical safety

The following Figure 12 illustrates data in relation to the training of electrical safety (NR 10), and it compares with risk perception of electric shocks and the percentage of workers which used electrical isolation gloves (PPE).

The number of workers which perceived electrical shocks as risk was in accordance with the number of workers which undertook electrical safety training (NR 10). Electrical isolation gloves were used by a low number of workers, which could be explained with a low number of workers which were electricians. Other workers did not this PPE as they avoided any contact of this type. In this case, the electrical risk could be ranked as the highest, not only due to what show us statistics (FUNCOGE, 2018) and previous works (Barkokébas, 2014; Roberts, 2016), but also as workers are located in the area with several powered

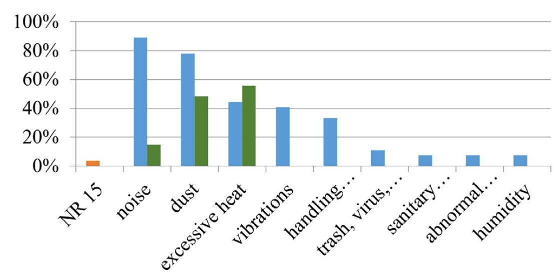

Figure 11. Unhealthy operations.

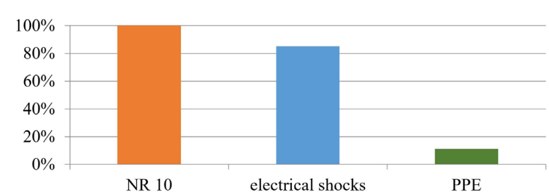

Figure 12. Electrical safety.

equipments with high voltage levels. The consequence of this risk could be fatal in just a matter of seconds. The risk includes the risk on low powered electric bus areas. The construction activity of electrical substations requires trainings on electrical risks, regardless of the employee's function.

5.2.3 Construction safety

The following Figure 13 illustrates data in relation to the training construction safety (NR 18) and training for working on height (NR 35), and it compares with the perception of risk of falls, fires and explosions, electrical and mechanical shocks.

The training on construction safety (NR 18) and working at heights (NR 35) was moderate (59% and 56% respectively). It was in accordance with the number of those which perceive falls (59%) as important risks for consideration.

Fires and explosions may occur due to the failures of electrical equipment and mechanical shocks, while falls from heights due to the worker conducting his activity on heights. Nevertheless, as falls represent a high percentage of accidents and death cases (Barkokébas, 2014), it was expected that workers would have a greater perception of this risk. The risk of falls is highly present as work is conducted on heights above 2 meters from ground level. Further on, falls can occur through the openings of trenches for passage boxes and equipment bases. A possible solution is to improve the number of safety signs. A common situation that causes an imminent risk of falling is to observe workers passing over box channels through the courtyard. The worker may fall on through a "false" cover, or a cover may rupture due to being prepared to support the workers weight, causing him torsions, fractures or even death. This could lead to unnecessary work leaves for long periods of time. Additionally, during rainy periods, slippery floors should be cleaned accordingly.

5.2.4 Other safety concerns

There were a low number of workers trained in fire safety, but the risk perception on fires and explosions was represented by high number of workers. This could be explained with moderate number of those which were trained for fire safety but through another standard (for example the training on construction safety which includes fire safety). Fire and explosion represent a high and very present risk. It is enough to observe the fire walls construction around the power transformers, which have the function of not propagating fire and confining the fragments of an exploded-equipment near its original area. In case of fire, a possible failure to insulate any equipment can possibly cause an explosion. Therefore, the use of Personal Safety Equipments and Common Safety Equipments is more than fundamental.

Similarly, the number of those trained for working with flammable and combustible materials was low, while the risk perception was represented by medium number of workers. Flammable liquids such as Diesel in the Emergency Generator Set require care when handling with or getting closer to it. Cigarettes are strictly prohibited in this area, since any spark can generate a disastrous fire that can be spread. It is recommended that everyone is familiar with the use of extinguishers as well.

In third place for risk perception it was traffic accidents. Workers are conscious that long journeys between their homes and workplace pose a risk for traffic accident. Although it is an external factor, it is important to consider it and to give workers recommendations on using defensive driving, not to consume alcoholic beverages and leave their home early to avoid rush-hours and reduce this risk.As the substation construction environment is usually far away from large urban centres, a risk from several poisonous animals should be considered: like snakes, scorpions, rats, which could hide in cable-ducts inside the passage boxes. Before opening them, caution is required and no one should perform any activity by himself.

The Repetitive effort, such as carrying cement bags and handling heavy equipment, require the worker to be careful when distributing loads with someone else, observe their posture when squatting and to climb adequately. Many accidents occur because of needless rush.

Another very present risk is while cutting materials. For this task are used various tools and instruments

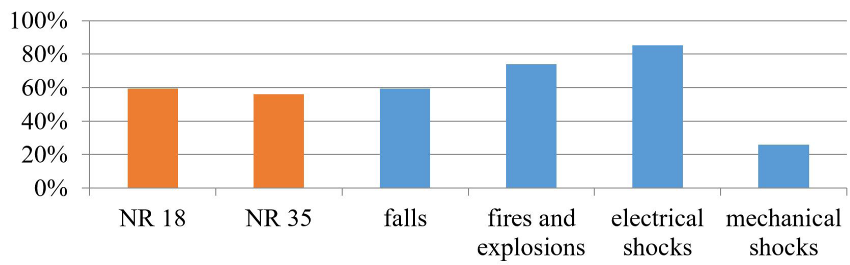

Figure 13. Construction safety.

such as: nails, wires, circular sawings, machines, drills, hoes, shovels, pliers, hammers, among others. Some of them can even be oxidized, bringing serious health risks such as tetanus. The equipment storage and organization with signs indicating the equipment´s name and risks warning are very important. Therefore, edgy materials should be stored and packaged properly, in order to avoid that improper manipulation causes undesired accidents to workers.

Cement is a very common chemical product used in the construction industry. It is necessary that workers use appropriate gloves to avoid direct contact with the skin, as cement can cause risk for professional dermatosis.

6 Conclusions

The construction held at electrical substations represents a dynamic environment where workers with different areas of expertise work simultaneously.

The construction process of the electrical substation was found to pose several risks depending on its phase. When using mechanical tools, it is necessary to conduct a preliminary risk assessment. Once the excavations are finalized, fall-protective measures should be applied around all holes and ditches. The concrete vibrators and all electrical equipment should be earthed. During the construction of fire-walls scaffolds should be used and fall-protective measures should be applied. Truck-crane should be avoided as moving parts in the proximity of powered transformers posegreat risk of electrocution. During the process of grounding all elements should be identified and employees should not have any contact with the soil loop.

Workers were found to apply several risk analysis tools, while the most commonly used was the PRA. There is relation between training, risk perception and adequate use of PPEs. When workers were not trained for working with some risks, they exaggerated or underestimated the risk. Workers were mostly trained for electrical safety, construction safety a working on heights, where the percentage of risk perception was in accordance with the percentage of workers which were trained to identify and manage those risks.

The conclusion of this study was that the construction of electric power substations brings several safety risks and that the instruction of workers allows an effective risk management, and can reduce the number of accidents in this type of working activity.

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