SAFETY RISK IDENTIFICATION FOR OPERATIONS AND MAINTENANCE IN AN EDUCATIONAL 13.8 kV ELECTRIC SUBSTATION

Paulo de Tarso do Nascimento[1], Valéria Loureiro da Silva [1], Frederico Ramos Cesário[1]

[1] Centro Universitário SENAI CIMATEC, Av. Orlando Gomes, 1845 - Piatã, Salvador – BA, 41650-010, Brasil.

Abstract: This work relates to the identification and mapping of potential safety risks and mitigation measures for an educational 13.8 kV electrical substation, which was built in real operating conditions, ensuring compliance with all necessary rules in interventions with safety, according to the peculiarity of the users, instructors and students. Due to the scarcity of information to validate the study, a semi-structured qualitative interview was conducted with relevant professionals. The interviewed specialists pointed out the need for avoiding distractions, strictly following procedures and knowing the installed equipment, besides the technical and regulatory norms.

Keywords: Electrical safety procedures; educational substations; 13.8kV substation safety; electrical risk control.

IDENTIFICAÇÃO DE RISCOS DE SEGURANÇA NAS OPERAÇÕES E MANUTENÇÃO DE UMA SUBESTAÇÕES ELÉTRICAS DIDÁTICA DE 13,8 kV.

Resumo: Este trabalho diz respeito à identificação e mapeamento de potenciais riscos de segurança e medidas de mitigação para uma subestação eléctrica de 13,8 kV, construída em condições reais de funcionamento, garantindo o cumprimento de todas as regras necessárias nas intervenções com segurança, de acordo com a peculiaridade dos utilizadores, instrutores e estudantes. Devido à escassez de informação para validar o estudo, foi realizada uma entrevista qualitativa semiestruturada com profissionais relevantes. Os especialistas entrevistados salientaram a necessidade de evitar distrações, seguindo rigorosamente os procedimentos e conhecendo o equipamento instalado, para além das normas técnicas e regulamentares.

Palavras-chave: Procedimentos de Segurança em eletricidade; Subestações didática; Segurança em subestações de 13,8kV; Controle de risco elétrico.

1. INTRODUCTION

A power substation consists of a set of electrical equipment of various characteristics and functions that, installed in an integrated manner among themselves, allows the power flow regulation, change and control of electrical quantities of voltages and currents, and ensure the protection of the electrical system [1]. ANEEL Normative Resolution No. 479 of April 3, 2012 complements the definition of the part of the power system that comprises, besides the devices, civil works and assembly structures [2-3]. The construction, expansion, renovation, operations and maintenance of substations are common activities in electric power companies, industries and other consumers, as it involves a complex process of information, regulatory and technical compliance and legislation [4]. Therefore, it requires several professionals with specific skills and knowledge in construction, operation, maintenance and renovation for it to be successfully executed. It stands out then the importance of training adapted to the various activities developed in this type of facility.

The electrical panels, equipments and devices that compose the substations generate of strong electric and magnetic fields that require the creation of protection rules to enable electromagnetic compliance. Visual inspection or even technical visit to this type of installations present risks pertinent to the installation itself even if there is no physical intervention [5-7]. The simple existence of unshielded energized conductors connected to equipment presents possibilities of air ionization, changing its dielectric properties and creating a situation favorable to the occurrence of electric arcs [6]. The risk of arc generation is more common on humid days. The emergence of small arcs inside the equipment is a situation controlled by the protection system during operation of the substation. Due to the diversity of conductor insulations present in the market, it is necessary to be careful, because they bring, according to the physical arrangement of the installation, changes in the magnetic flux of the field lines around them, as well as electromagnetic interactions between them. Thus, it must consider the eventuality of interruption or failure in their insulation and, consequently, may represent additional risk if there is inadvertent contact with energized electrical parts [5-6]. Thus, it is paramount the implementation of risk reduction measures to avoid people exposure to possible risks and reduce changes in the operation of the installation during interventions or even inspections.

A 13.8kV educational substation is being implemented at Senai allowing the training of students from diverse backgrounds on activities related to maintenance, operation or inspection, considering the characteristics of the installation, the pertinent legislation, technical standards, operating procedures and safety aspects for such equipment. This substation needs to allow for interventions by teachers and students in a safe, didactic way without being disconnected from the reality found in the Electric Power System (SEP) or consumer installations that receive electrical energy at high voltage. This work describes the identification of relevant risks for the substation use obtained through an interview of qualified professionals that will be using the substation for training activities. The risks were than mapped and classified for a posterior mitigation effort [6-7].

2. METHODOLOGY

A literature search on educational high voltage substations and security was performed on the following databases: Scopus, ScienceDirect and CAPES CAFÉ. The only relevant information found were corporative training material that did not fully meet the objective of safety for an educational substation. Therefore, a qualitative semi-structured survey was conducted to bring in the perspective of the instructors and users of the substation. These are qualified and skilled professionals with training in the area of electricity and professional experience in electrical substations, in addition to teaching in disciplines related to this type of installation and in various modalities such as: Post-Graduation, Graduation, Technical and Qualification Training.

A questionnaire containing thirteen open questions was developed and used without time limit for the answers, allowing the professional to discourse according to their experience. There were three types of questions: demographic, educational and safety in electrical substations. The objective of the first two groups of questions was to validate the desired professional and pedagogical experience of the interviewees and the last group to collect the relevant aspects regarding safety in electrical substations for didactic purposes. Before starting the interviews, the questionnaire was tested and validated. Meetings were held with the researchers aiming to analyze each of the proposed questions and possible answers followed by the application of the questionnaire with 2 people for validation of the consistency of the questions and answers and time for the interview. After adjustments, the questionnaire was then used for the interviews. A term of informed consent was signed by each of the interviewees to allow for the use of the information in this research.

The interviews were conducted with 13 interviewees over the course of a month during a previously scheduled time. Around 240 minutes of video and audio recording were produced, and each answer was transcribed, tabulated, and grouped by question. All the mentioned expressions related to security were recorded grouped as well. It was noticed that those expressions could be grouped according to the themes used in current Technical Standards, which facilitated further analysis and provided more consistent graphics generation.

3. RESULTS AND DISCUSSION

It is important to highlight that the public interviewed need to have knowledge and experience in both subjects: teaching in disciplines related to electrical substations and experience in this type of facility. That would allow them to effectively identify electrical and additional risks as well as determine the criteria for access and performance of activities in a teaching substation. The population interviewed was 85%

male, with an average age of 57 for men and 41 for women, and professional experience of 27 and 16.5 years respectively. As shown in the graph in figure 1, 60% of the interviewees have an Electrical Engineering and/or Electrical Technician degrees, which are qualified or licensed to develop activities in electrical substations.

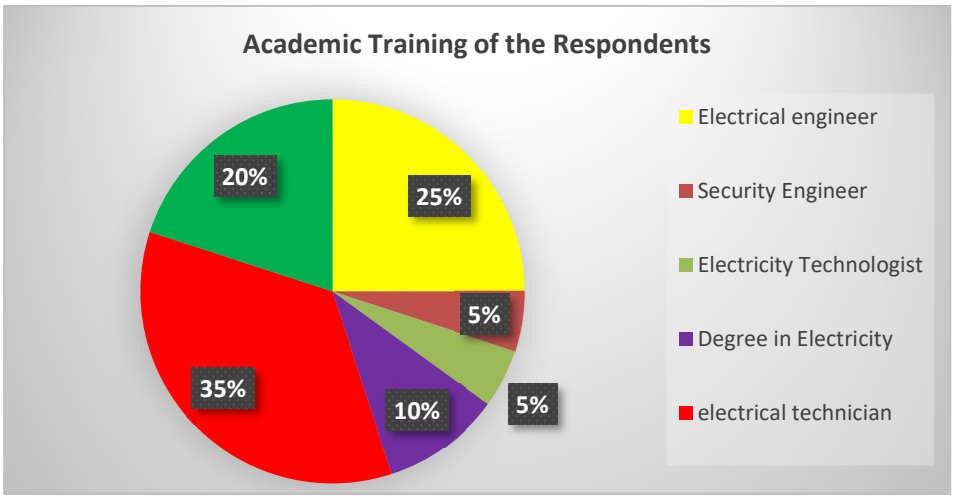

Figura 1- Academic Training of the Respondents

The graph in figure 2 shows that the interviewees teach courses in all the modalities selected in the study, but it is important to point out that 56% of this population teach courses that form qualified professionals and, therefore, need to perform operational activities in electrical substations. Therefore, the interviewee information shown in Figures 1 and 2 ratify that the selected population meet the study´s objective and is qualified to identify the inherent risks associated with a high voltage substation as well as additional risks coming from the educational use.

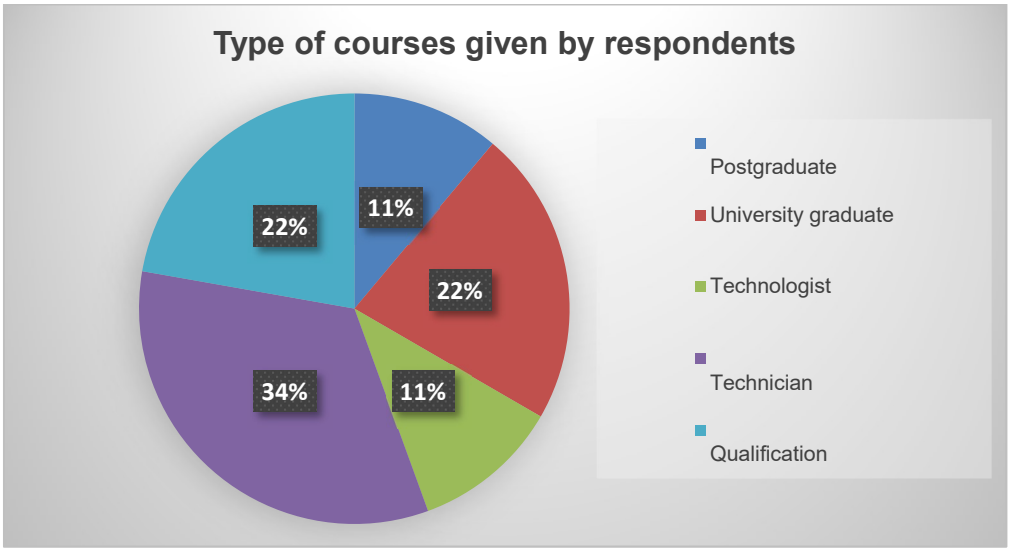

Figura 2 - Type of courses given by respondents

The answers to the question *"Which risks are relevant to perform activities in the substation?"* were tabulated and the results presented in the graph in Figure 3. The respondents listed the electrical risks as the main element of control regarding exposure followed by procedures. The terms safety procedures, knowledge of equipment and operating procedures, which are associated with electrical risks and adequate procedures, were repeated many times in the interviews. This is not surprising since electric substations, due to their construction characteristics, need constant interventions, and activities related to maintenance and operation of equipment are inherent to their routine. That is the case for all electrical substation and is not restricted to the educational nature of the substation in question.

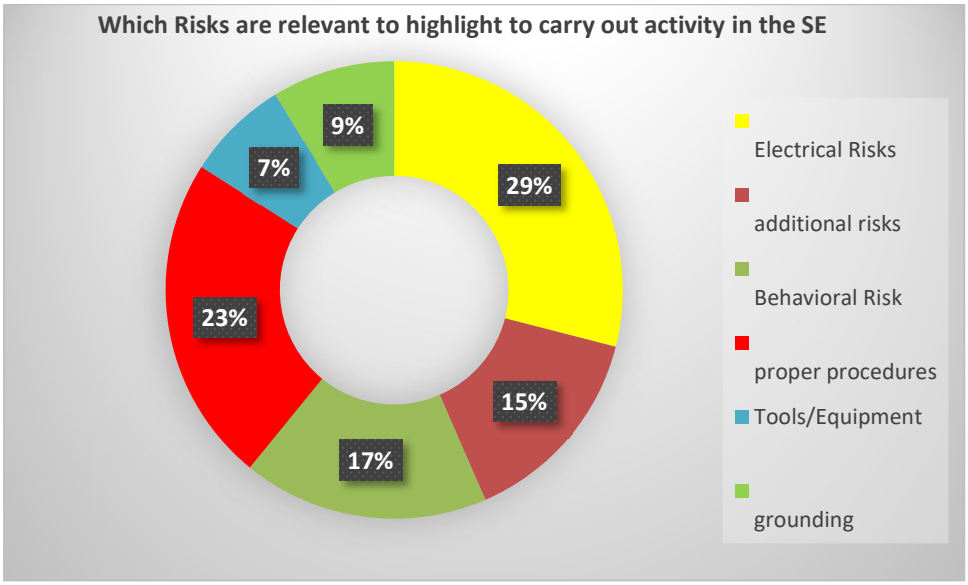

Figura 3 - Which Risks are relevant to highlight to carry out activity in the SE

In third, with 17%, came the *Behavioral risks,* which are the risks associated with the conduct of the individuals and were broken down in the graph in figure 4. This graph reinforces the high degree of importance of establishing and following rigorous procedures and avoiding distractions to prevent exposure to electric or additional risks. Although those are important to handling any substation they are more important for an educational substation where students with different level of maturity and incomplete knowledge of the equipment are present, as were also pointed out in Figure 4.

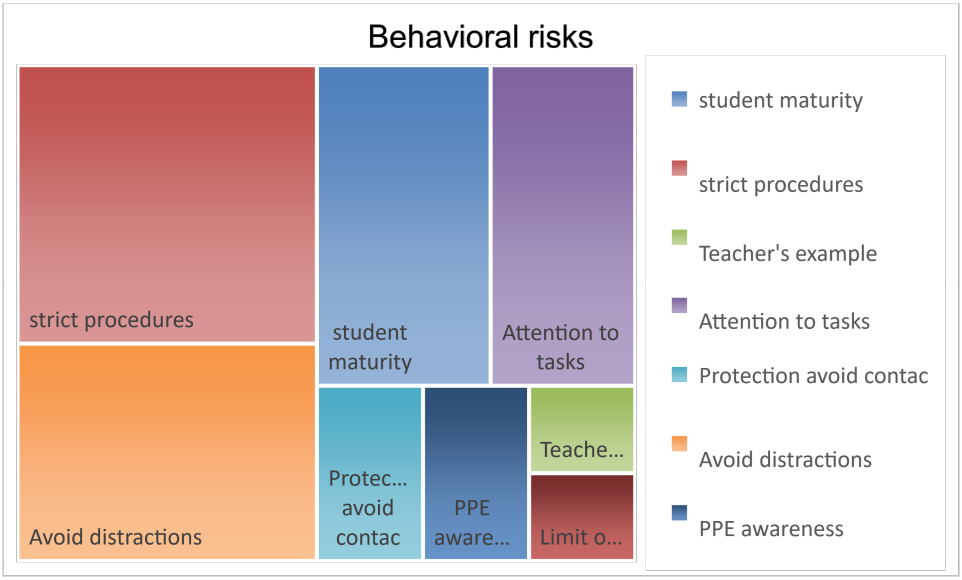

Figura 4 - Behavioral risk

4. CONCLUSION

This work relates to the identification and mapping of potential risk and mitigation measures for an educational 13.8 kV electrical substation. It was built for emulating real operating conditions, ensuring compliance with the legal and technical rules for carrying out operational, maintenance, and inspection activities with safety. Due to the peculiarity of the users, instructors and students, it requires additional security measures. The difficulty in finding specific literature on the topic of safety for an educational substation, led to the conduction of interviews with electrical professionals, professors and instructors with experience in this type of electrical installation. The results of the interviews allowed for the identification of relevant information to be considered in ensuring the safety of users of the high voltage educational substation. The need for prioritizing the development and ensuring compliance of specific procedures regarding electrical and additional risks as well as considering behavioral aspects were highlighted by the interviews.

Acknowledgments

We thank the SENAI CIMATEC for access to the educational substation and the interviewed instructors and professionals for their invaluable contribution to this work.

5. REFERENCES

[1] PAULO DE OLIVEIRA FRONTIN (Brasília) (org.). **Equipamentos de Alta Tensão**: prospecção e hierarquização de inovações tecnológicas. Brasília: Goya Editora Ltda, 2013. 934 p.

[2] BRASIL. Constituição (2012). Resolução Normativa nº 479, de 03 de abril de 2012. **Condições Gerais de Fornecimento de Energia Elétrica de Forma Atualizada e Consolidada**. Brasilia, DF, 12 abr. 2012. p. 116-116.

[3] SILVA, Hudson Batista da. **Simulador de uma subestação elétrica para ensino de princípios básicos de eletricidades**. 2017. 89 f. Dissertação (Mestrado) - Curso de Engenharia Elétrica, Universidade Federal do Pará, Instituto de Tecnologia, Universidade Federal do Pará, Belém, 2017. Cap.6

[4] MAIA, Willian Felipe Silva; EKEL, Petr Iakovlevitch; COSTA JÚNIOR, Pyramo Pires da (ed.). AVALIAÇÃO DE RISCOS DE SUBESTAÇÕES PARA A PREVENÇÃO DE ACIDENTES:: análise de fatores contribuintes. **Anais do XIviii Sbpo: Simpósio Brasileiro de Pesquisa Operacional.** Vitória, p. 280-291. 27 set. 2016.

[5] RESENDE, Filipe Barcelos. **Proteção Elétrica em Subestações**: : uma abordagem sobre a energia incidente. 2016. 101 f. Dissertação (Mestrado) - Curso de Engenharia Elétrica, Engenharia Elétrica, Universidade Federal de Minas Gerais, Belo Horizonte, 2016. Cap. 8.

[6] TAVARES, Filipe André Maduro. **Aplicação Informática para Dimensionamento de Barramentos em Subestações**. 2015. 168 f. Dissertação (Mestrado) - Curso de Engenharia Elétrica e Automação, Engenharia Eletrotécnica de Energia e Automação, Instituto Superior de Engenharia de Lisboa, Lisboa, 2015. Cap. 6.

[7] ALMEIDA, V. C. (2011) **Sistema de Treinamento de Instruções de Operações Internas e Operação de Sistemas Elétricos baseado em um Ambiente Virtual de Aprendizagem**. Dissertação de Mestrado em Engenharia Elétrica, Publicação: PPGEA – 462/11 Departamento Engenharia Elétrica, Universidade de Brasília, Brasília, DF, 119p.

6. OTHER INFORMATION

a) Manuscripts and information included therein are the responsibility of the authors and may not represent the opinion of **VIII SIINTEC**.

b) The authors accept that **VIII SIINTEC** has full rights to the submitted manuscripts and may include them in the proceedings, print them and disclose them, without payment of any kind.

c) Manuscripts will be evaluated by reviewers invited by the Scientific Committee of the Event. Only accepted manuscripts can be presented and published at the event.

For additional clarifications, contact:

Organizing Committee of the Event - *siintec@fieb.org.br*

SENAI CIMATEC