View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by American Scientific Research Journal for Engineering, Technology, and Sciences...

American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

© Global Society of Scientific Research and Researchers

http://asrjetsjournal.org/

Analysis of Harmonic Vibration Applied as Assistance to Maneuvering High Voltage Switches

Ademilson Setti[a]*, Juliano Daronch[b], Lucas Dalla Maria[c], Charles Leonardo Israel[d], Giulia Zanella[e], Luciano Favreto da Rocha[f]

[a,b,c,d,e]*University of Passo Fundo, Passo Fundo, 990520-900, Brazil*

[f]*State Power Energy Company (CEEE), Porto Alegre, 90160-091, Brazil*

[a]*Email: lintec@upf.br*

[b]*Email: lucianofr@ceee.com.br*

Abstract

High voltage switches are equipment that allow or block the electricity flow from one point to another. This paper presents an experimental approach, focused on the analysis of mechanical vibration applied in the maneuvering process of the switches. In this study, a maneuvering process was reproduced as it is done in industry, that is, free from vibration; then, the proposal to use mechanical vibration as an alternative aid to increase maneuvering process was tested, using the system proposed by patent BR 10 2013 020198 7. The quantitative parameters analyzed in this study are: vibration frequencies that provides torque relief for opening / closing maneuver, camshaft torque in the maneuvers, bolt torque, mechanical stress and deformation from different parts of the switch structure. In the present work, the obtained data suggests that harmonic mechanical vibration provides technological advances for the disconnecting switch system, such as, the increase of opening and closing maneuvering capabilities. It was also found that mechanical vibration does not affect the structure for the vibration requirements adopted during a survey. Thus, the quality of closure presents positive advances with the use of harmonic mechanical vibration, validating a solution proposed in the patent BR 10 2013 020198 7.

Keywords: High voltage switches; experimental study; mechanical durability; harmonic vibration; vibration frequency.

---

* Corresponding author.

1. Introduction

Electrical substations are bridges of convergence between the input and output of distribution lines, in which transformers change the voltage, increasing or decreasing it, as needed. Thus, the operation of electrical system components becomes safer, aiding in the elimination or reduction of power outages. Substations have devices called high voltage switches. These mechanical equipments are used in sectioning maneuvers, a process responsible for isolating electrical circuits. When the opening maneuver is performed, the circuit is de-energized and blocked for power, thus making the work of engineers and technicians in the industry safer. The opening and closing processes of the high voltage switch are performed through a control room. The opening maneuver causes the energy passage to stop, causing the switch stem to move away from the fixed contact, interrupting the flow of energy. On the other hand, the closing process causes the high voltage switch rod to position itself within the fixed contact. Thus, the key closes and the electrical circuit is restored. It should be noted that this closing process requires the presence of technicians in the substations to monitor the maneuver, in order to prevent the energy passage being reestablished without a satisfactory connection between the switch and its contact. Unsatisfactory closing condition can cause a hot spot, characterized by increased temperature in the contact region between the main contact blade and the fixed contact due to reduced contact area. Thus, [1] developed a study on high voltage switches, aiming at mitigating the high voltage switch malfunction [2] proposes the use of an external high voltage switch excitation source to reduce the friction between the fixed contacts and the mobile contact rod, in the opening and closing operations of the disconnect switch. Through this proposition, the University of Passo Fundo (FUPF) and the State Power Energy Company from Rio Grande do Sul (CEEE) obtained the right to exploit the patent BR 10 2013 020198 7. Through the patent BR 10 2013 020198 7, and the study [1], the FUPF and CEEE were awarded with funds from the National Electric Energy Agency (ANEEL) for the development of a research and development project to use the mechanical vibration in the process of operating the high voltage switches. Thus, the aim of this study was to investigate the possibility of using mechanical vibration of the mobile contact rod to facilitate the opening and closing maneuvers of the high voltage switches, to compare the current process with the process proposed [1], as well as to analyze various mechanical parameters how vibration frequencies that provides torque relief for opening / closing maneuver, camshaft torque in the maneuvers, bolt torque, mechanical stress and deformation from different parts of the switch structure.

2. Objectives

2.1 General objectives of the study

Experimentally evaluate the influence of mechanical vibration on the opening and closing maneuvers of high voltage switches comparing the current process with the proposal [1].

2.2 Specific objectives

The specific objectives of this study are:

- Investigate the parameters of mechanical stress, strain, torque on bolts, torque on control box shaft, opening / closing quality and frame frequency.

- Perform the experimental tests of the opening and closing maneuvers in the current execution condition, with free vibration and the proposed use of forced vibration under harmonic excitation;
- Perform a test to verify the frequency required for torque relief in the switch box;
- Perform statistical analysis comparing the two situations studied.

3. Materials and methods

For the execution of the experimental procedure, it is important to present a broader overview of the way this section will be conducted. It is part of the general objective of the study to evaluate the influence of mechanical vibration on the opening and closing process. The Lorenzetti 242 kV high tension switch will be used for the tests. The free from vibration tests will occur only to repeat the maneuvering process, while the harmonic mechanical vibration process will occur with vibration energy generated by a unidirectional mechanical vibrator. The unidirectional mechanical vibrator allows the energy to be transmitted only in one direction. Therefore, the forced harmonic vibration was obtained through a set of eccentric masses, fixed on axes and driven by gears connected to an electric motor. The unidirectional movement is given by the positioning of the eccentric masses. The tests begin by verifying the frequency and masses required to reduce the torque required to move the main blade rods. Then, the 100-maneuvering tests for disconnecting and closing the disconnector were performed using free vibration and forced harmonic vibration, monitoring parameters such as mechanical stress, strain, frequency, spindle torque, opening and closing quality, and the structure’s screws torque. We have thus sought to divide the sections of this chapter so that they are interconnected and at the same time independent. The first section 3.1 is dedicated to the test bench, starting with the models of disconnecting switches received from CEEE, choosing the place to build the bench, positioning the bases to support the keys, followed by the design and manufacture of structures required for fixing, as well as the data acquisition system. The second part will deal with the procedure used to perform the tests and what are the standards studied for the formulation of the methodology. This section aims to present a kind of standard operating procedure that can be used in other models of high voltage switches besides those tested in the present study. Finally, in the last section will be presented the variables that will be monitored so that, afterwards, the obtained data passes through digital processing, then followed by analysis of variance to be correctly compared, then proven or not the improvement in efficiency of harmonic mechanical vibration for closing and opening of high voltage switches.

3.1 High voltage switch utilized on this study

The Lorenzetti 242 kV model has three phases interconnected by metal rods, and when activated by control box, the three phases simultaneously move, to the direction of the fixed contact (closing) or in the opposite direction to the fixed contact (opening). Figure 1 shows the 242 kV Lorenzetti switch model present in the CEEE - Santa Marta substation.

The 242 kV Lorenzetti switch is also composed by a support structure, isolators, movable contact and fixed contact. It also has, in its control box, a mechanism that allows the drive to be done manually, remotely or through the command box (actuation performed by the buttons of the command box itself).

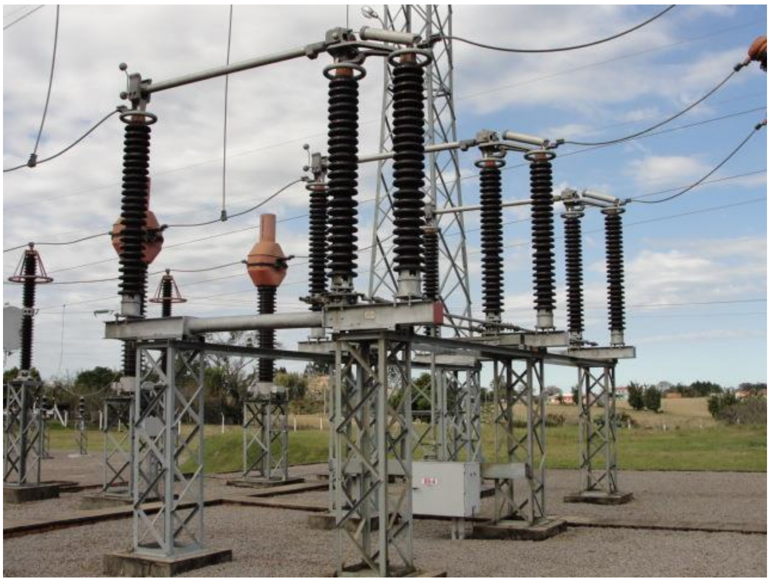

Figure 1: High voltage switch model studied

3.2 Mechanical vibrator

The vibration required for the study was obtained from an external source, with a known frequency. It is important to note that the purpose of the structure excitation is to amplify the natural frequency response of the entire set, as it is desired to prevent the structure collapse caused by the resonance effect. The use of the energy generated by the vibrator aims to reduce the undesirable effects caused by friction in closing / opening of the main contacts (fixed contact and moving contact). The best known alternative to friction reduction is the use of lubricants, but the need for them to have conductive properties considerably reduces the availability of lubricants in market. However, the application of lubricant in the equipment placed in a substation subjected to open weather, causes dryness, thus becoming undesirable for application on the contacts, as described by [1]. In this study the vibrator used was a directional model based on the principle of energy oscillation, thus directing the energy in the direction of movement. The model and other information regarding the motor vibrator used can be found in [3]. The energy oscillation is generated by two or more eccentric masses that have opposite directions of rotation with a constant angular velocity, thus causing the total mass to excite, causing it to vibrate. Due to the need to attach the vibrator to the switch structure, the design of a mechanical support for the vibrator became essential. In this project, two boundary conditions were considered. The first concerns fixing the frame support so that it could be allocated in other positions. In the second, the objective was to directly drive the drive rod.

3.3 Data acquisition

We sought a system that monitored mechanical stress, strain, frequency and torque on the control box shaft. In this phase some tools were used so that a primary data collection could be performed, so that some necessary components could be defined. Then defining the installation of uniaxial strain gauges at various points on the switch, ½ bridge strain gauges at 45 ° to measure torque on the tree shaft, torque wrench to measure the force required for manual maneuvering, load cells to measure the force the shaft makes against the contact and others.

For strain gage measurement, the variation of the electrical resistance of the strain gage was used, which is processed through the data acquisition system, where this variation in the electrical resistance is transformed into a numerical value that represents the deformation of the analyzed specimen. With the use of strain gages, it will be possible to acquire and process important data for this research, such as mechanical stress, strain, and bolt torque. Next, in Figure 2 you can see the points where the strain gages were monitored.

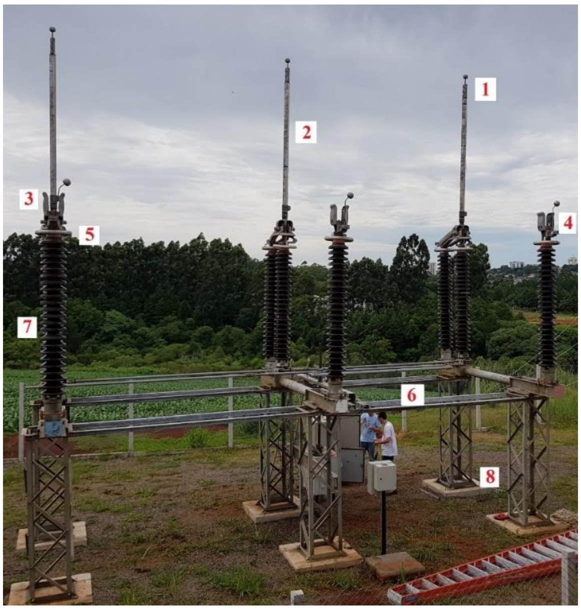

Figure 2: Strain gauges points of installation

Below, in Table 1 is a description of each instrumented point.

Table 1: Description of Instrumented Points.

Point	Description
1	Main contact
2	Middle of the main blade stem
3	Main blade base
4	Connection terminal
5	Main blade rotating base
6	Transmission tube
7	Fixed porcelain column
8	Support structure column base

This research also shows the need for monitoring frequencies caused by the switch itself. This monitoring is relevant in free vibration analysis as well as in forced harmonic vibration analysis. Accelerometers were used for gathering acceleration data at specific points to enable frequency calculations in the switches. In the Lorenzetti 242 kV switch, the accelerometers were positioned at point 1, also with a 50-cycle sampling. To obtain the signal frequencies, the Fast Fourier Transform (FFT) algorithm was used, and then Power Spectral Density (PSD), or power densities was also used. This technique is most commonly used for applications such as measured vibrations or random characters.

3.4 Command Box Torque Relief Test

During the development of the study, it was necessary to perform tests to verify the torque variation in the switch box when subjected to forced harmonic vibration and free vibration. During this section of the study, it was necessary to use a digital torque wrench for data collection. The fuse start and end rotation position has been set so that the rotation is sufficient to remove / place the main stem blade in the fixed contact. Subsequently, a battery of 50 opening and 50 closing tests was performed to analyze which condition would require the highest torque.

3.5 Other equipment

A frequency inverter was used next to the vibrator so the electric motor rotation of the mechanical vibrator could be changed. The use of the frequency inverter has as its main purpose to easily vary the frequency until the ideal frequency is found, that is, the frequency that allows the contacts to close and that does not cause the resonance phenomenon in the equipment. The use of the torque wrench is of paramount importance, as there are recommendations that suggest that the bolts be used only once, and that after the total removal of the nut, the bolts are replaced with new bolts, thus reducing the possibility of bolt failure. According to [4], 85% of failures in bolted joints are due to fatigue and 45% related to assembly error. Based on this concept and observing that the support structures of the switches could contain screws used more than once, a complete replacement of the screws of the support structures was performed. The old frame fixing elements have been replaced by new Class 8.8 size M12 screws with normal metric thread, having a yield limit of 640 N / mm².

3.6 Experiment methodology

It is well known the importance of operational procedures for the detailing of tasks and, consequently, a standardization of work execution. With this bias in mind, this section will study and present a testing methodology for high voltage switches experimentation. The construction and development of this section is based primarily on regulatory standards in the Brazilian and global electricity sector.

3.7 Guidelines based on Standards

This section is based on the study of the following standards:

- ABNT NBR IEC 62271 – 102:2006 [5];

- ABNT NBR IEC 60694 [6];
- ABNT NBR 7571 [7];

Prior to the guidelines contained in the standards, it was stablished a sequence of steps that could verify the correct operation of the switch components. The operation of checking switches was made through the control box driven by electric engine. Prior to this, the manual process of closing and opening the disconnect switch was performed to verify the correct operation of the drive mechanisms. Given the nature of this study is focused on the evaluation and validations of solutions present in the patent BR 10 2013 020198 7, the study of the standards stood out the [5], which is responsible for dealing with mechanical durability tests, for high tension switches. It is important to clarify that tests aimed at electrical tests were not performed, same as the ones seen in [6], which is responsible for measuring the resistance of circuits and dielectric tests. Reference [5] provides values for mechanical durability operation that the switches must be able to withstand, these values are related to the maintenance specified by the manufacturer. As shown in Table 2, the only difference between the M1 and M2 switch disconnector classes is the duration of the test, so this study is building considering the M2 class, that is, a battery of 10,000 cycles would be run, for each changed parameter.

Table 2: Adapted from [5], high voltage switches classification.

Class	Switch type	Number of cycles per operation
M0	Standard switch (normal mechanical strength)	1.000
M1	Switch used with equal class circuit breaker (extended mechanical durability)	2.000
M2	Switch used with equal class circuit breaker (extended mechanical durability)	10.000

With the disconnect switches mounted on the test bench, some guidelines expressed in the standards were applied, such as the verification of the force required for manual closing of both studied models of switches. With the application of this item, we sought to ensure the correct operation of the switch, just as happens in substations. Prior to the data collection, the test was performed to verify the torque relief required to perform the opening and closing maneuvers. For this test a torque wrench was used. Several data from the test bench were monitored and collected. Reference [5] suggests that some parameters to be monitored, such as operating time, opening / closing quality, maximum power consumption, among others. In the present study, as it is the validation of a new solution from the patent BR 10 2013 020198 7, other parameters will be monitored, besides some suggested by the standards such as:

- Quality of opening / closing;
- Mechanical tension;

- Deformation;
- Torque on the control box shaft;
- Torque on the screws;
- Frequency of the switch.

The test battery was divided into 10 series, each session having 10 opening and closing cycles, following the guidelines contained in the standards, to evaluate the operating characteristics. In the 1000 cycle series intervals, maintenance and mechanical adjustments are allowed, but subcomponent replacement, such as contacts was not performed, orientation is in accordance with [5]. At this stage of the study, it was necessary to verify the mechanical vibration as a relief factor for the opening / closing maneuvers of the switches. A torque relief test was required on the switchgear control boxes when opening and closing. For this, we tried to vary the frequency and mass of the vibrator until the best setting, which would allow torque reduction, was found. For this, the vibration frequency of the vibrator was varied, and then using a digital torque wrench coupled to the manual opening system of each switch, the opening and closing operation was performed. With the digital torque wrench, the torque tracking was done for each frequency tested. Knowing that the models of switches studied ended their depreciation time, as directed by ANEEL, some mechanical components presented structural failures. Thus, it was verified the need to define a new sampling number, which allows data collection and analysis, considering that the switches were produced long before the elaboration of the current standard [5]. Thus, 100 cycles for free vibration and 100 cycles for forced vibration under forced harmonic excitation were performed.

3.8 Descriptive analysis of data

Samples were collected and divided into 10 test batteries. In each test battery, 10 samples were generated, with a total of 5 monitored variables (mechanical tension, strain, control box shaft torque, switch frequency and opening / closing quality). For the torque in the screws, the samples were collected at the end of each test battery, so, for this variable there are 10 samples.

3.9 Torque on support frame bolts

The methodology performed for the evaluation of the torque of the support structure screws was performed according to [8].

4. Results and discussions

In this section we will present and discuss the results obtained in this study, comparing the monitored situations and also present a study of analysis of variance to then interpret the results obtained.

4.1 Standard operating procedure for testing

The aim of this experimental work was to automate the whole process of maneuvering the high voltage switches. In order to automate the operation of high voltage switch, thus enabling the tests to occur on rainy days since the test bench is exposed to the weather, a PLC was used. It has been programmed to open and close the high voltage switches, when activated, at a known scheduled time. For the operating procedure using forced harmonic vibration, the flowchart presented in Figure 3 was developed.

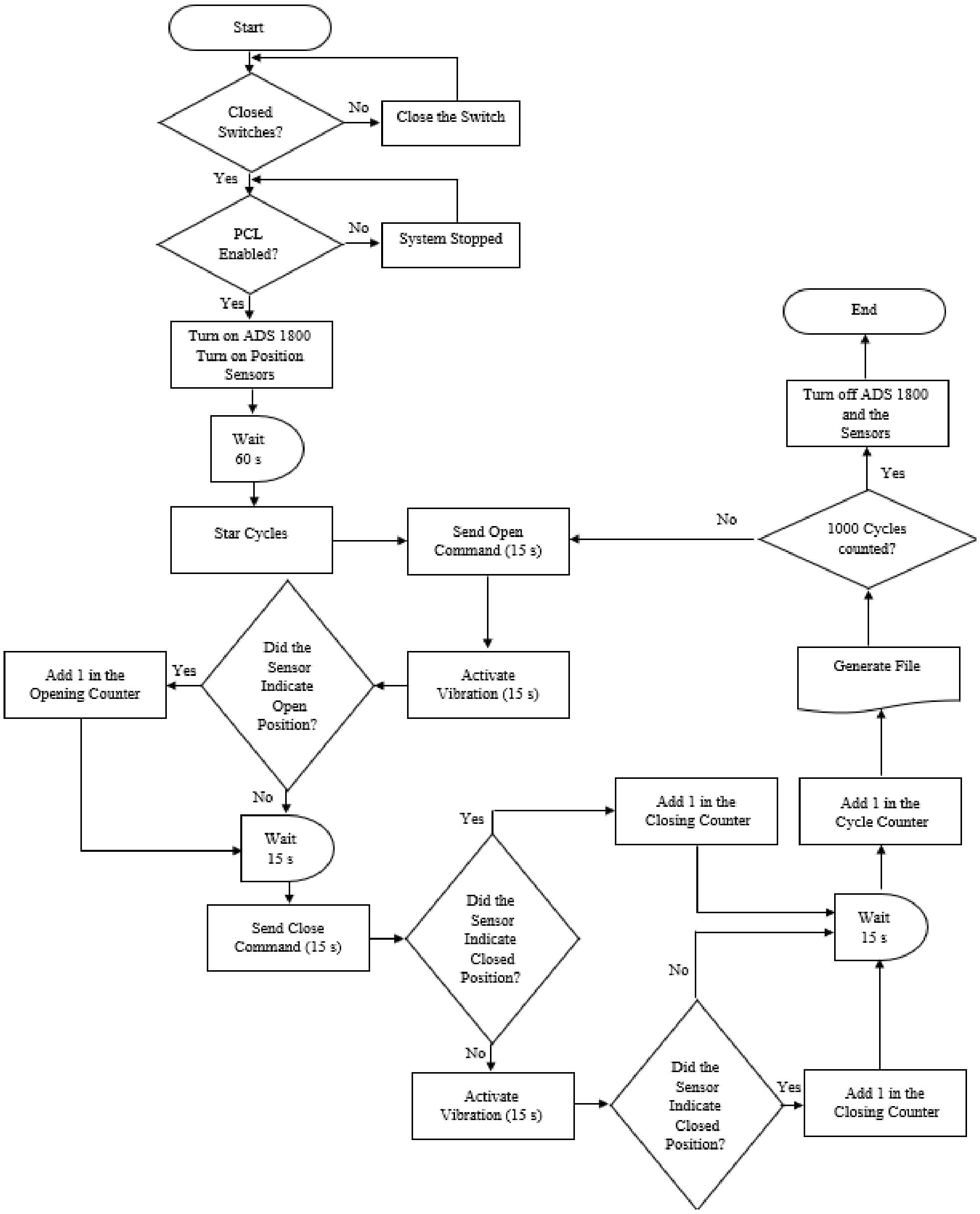

Figure 3: Standard operating procedure using forced harmonic vibration. Source: Author, 2018.

As shown in the flowchart in Figure 3, the first process of the operational procedure is to analyze whether the disconnect switch is in the closed position, which is the most usual position in electric power substations. Subsequently, it was sought to ascertain whether the PLC is connected to power and active. This verification was necessary so that the maneuver process automation can start, since the programming and the standard operating procedure were inserted in *ladder* language, thus enabling the activation of the data acquisition system and the sensors used to verify the disconnect switch’s position and the beginning of the cycles to meet the standards regarding mechanical durability. After a period of time, necessary to activate the components of the automation system, the PLC sent a signal for an interval of 15 seconds to open the disconnecting movable rod. Followed by the process of activating the mechanical vibration, this activation occurred through the programming inserted in the PLC that activated the unidirectional mechanical vibrator. Right after the sensor confirmed the opening of the disconnect switch, the counter programmed with the PLC added a unit in the opening cycle number. If the opening signal was sent and the sensor would not confirm the opening, it would wait for the 15 seconds necessary to dampen the structure, due to the impact generated by the mobile contact on the fixed contact, and the maneuver would not be added to the total opening cycles. Finally, a file was generated with the data of the monitored parameters (opening / closing quality, mechanical tension, deformation, torque in the control box, frequency of the disconnecting box) for each opening and closing cycle performed. It took 100 cycles (50 cycles of free vibration and 50 cycles of forced harmonic vibration), due to the time of manufacture of the keys, also so that mechanical and electrical components do not present failures due to the course of the study, a preliminary analysis will also be performed on the data obtained, as well as a visual assessment of the integrity of the structure and keys. It is important to highlight the use of the geometric figure that represents the delay function in flowcharts. This use took place in the 60 seconds between the activation of the position sensors, data acquisition system and the beginning of the cycles itself. This delay was shown to be necessary for all systems, including strain gages and accelerometers, to send data to the acquisition system and also to the data storage system, beginning the data recording. Finally, the delays arranged with the time of 15 seconds refer to two situations, in the first just after the position sensor process indicates the position of the mobile rod. This delay is important so that there is enough time to complete the opening and / or closing maneuver.

4.2 Lorenzetti 242 kV High Voltage Switch

In this section the results obtained in the free vibration test for opening and closing maneuvers will be presented and discussed. Figure 4 shows the mean strain values for the points where data were acquired. Deformations are presented for both free vibration and forced vibration under harmonic excitation. The point that presented the greatest deformation in the high voltage switch is the point called the transmission tube, represented in Figure 4 through point 6. The deformation in the transmission tube is justified by the kinematic chain of the high voltage switch. The transmission tube is responsible for transmitting the movement generated by the control box to the switch phases, causing the main contact blade to move from horizontal to vertical position in the opening maneuver and from vertical to horizontal position.

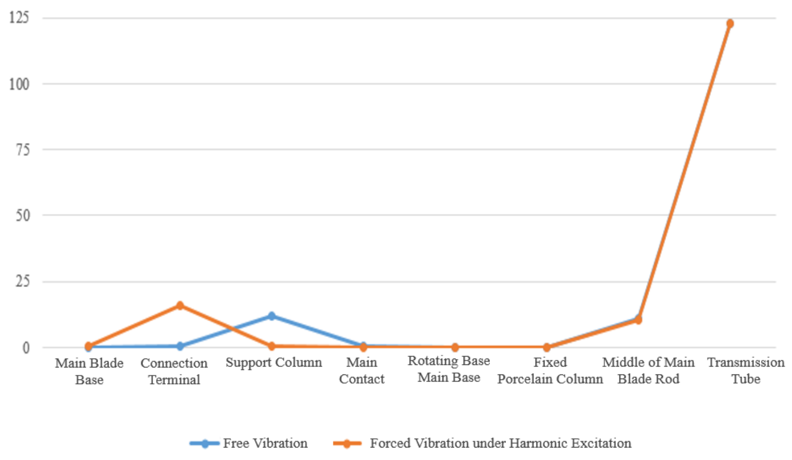

Figure 4: Lorenzetti 242 kV high voltage switch deformation.

4.3 Free vibration tests

The data collection parameter was the same as those used in subsection before. The points where strain signals were monitored during the study are shown in Figure 5, which also shows the deformation signal collected through the data acquisition system for the point that presented the highest deformation during the experimental tests for the switch transmission tube, the total duration of the cycle presented is 1 minute and 15 seconds. It can also be verified that the peak of deformation is reached at the opening of the sectioned phases until the phases are in vertical position, later reducing the load on the tube, returning the initial deformation as the cycle reaches the end. The maximum deformation reached in free vibration was 121,70 µm/m.

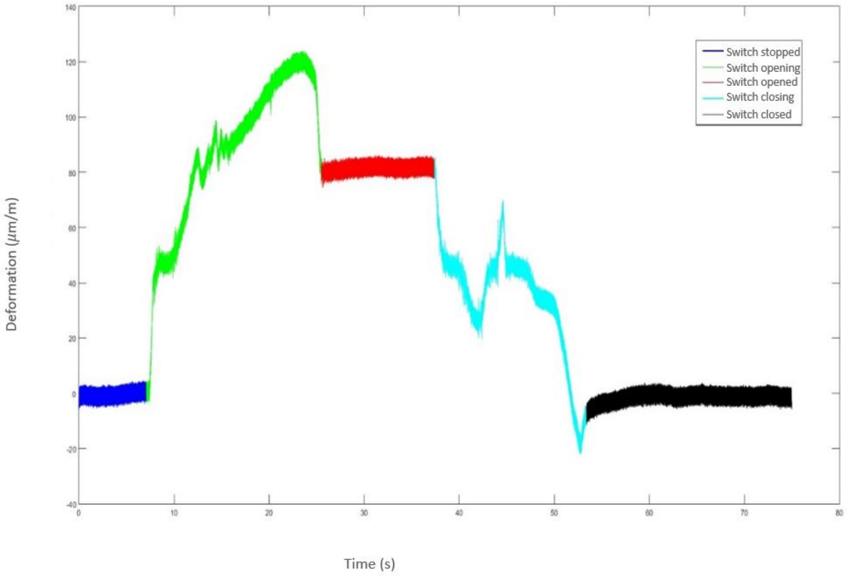

Figure 5: Deformation of the Lorenzetti's 242 kV transmission tube.

For a more detailed study the mechanical stress acting in the transmission tube was measured, for which was the Hooke's law below was utilized:

$$\sigma = E.\varepsilon \tag{1}$$

Where:

σ: Tension [Mpa];

E: Elastic coefficient of the material;

ε: Body deformation [mm].

The 100 cycles were compiled to provide a mean value for each cycle, represented in table 3 below. Considering 10 cycles for each group.

Table 2: Mechanical Tension Data and Deformation for Free Vibration in the Transmission Tube

	1º	**2º**	**3º**	**4º**	**5º**	**6º**	**7º**	**8º**	**9º**	**10º**
Deformation (µm/m)	121,70	118,82	99,24	99,45	121,64	98,71	120,79	118,24	117,49	120,38
Mechanical Tension (MPa)	24,34	23,76	19,84	19,89	24,32	19,74	24,15	23,64	23,49	24,07

Data regarding the frequencies present in the main contact blades near the fixed contact were also collected. Figure 6 shows the acceleration signal collected in one of the high voltage switch phases. From the signals presented, it was noted that the greatest acceleration occurs at the time of the opening of the main contact blade, with this data an FFT and a PSD were made so that the frequency data could be plotted.

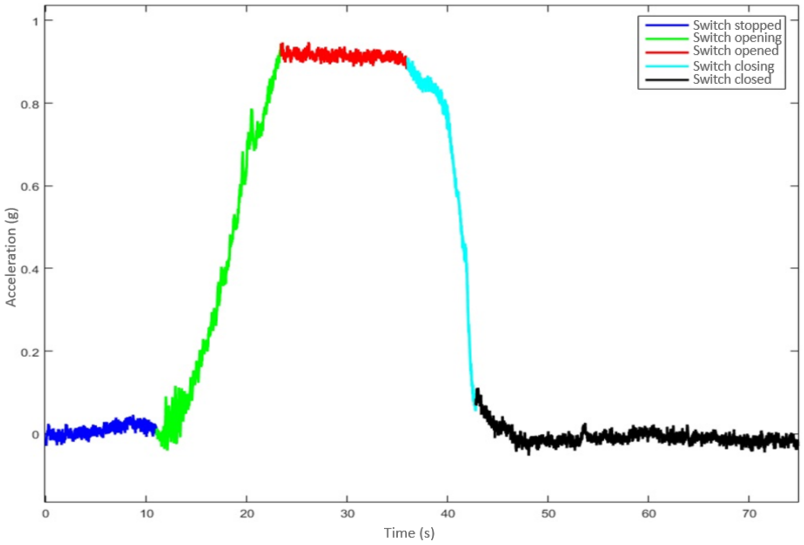

Figure 6: Incident accelerations on free vibration tests on Lorenzetti’s 242 kV switch

Figure 7 shows the frequency signature for the signal. By signing the frequencies for the vibration model of this section, it was observed that there are several frequencies during the opening and closing cycle, however, it was desired to evaluate the moment after the coupling of the main contact blade with the fixed contact.

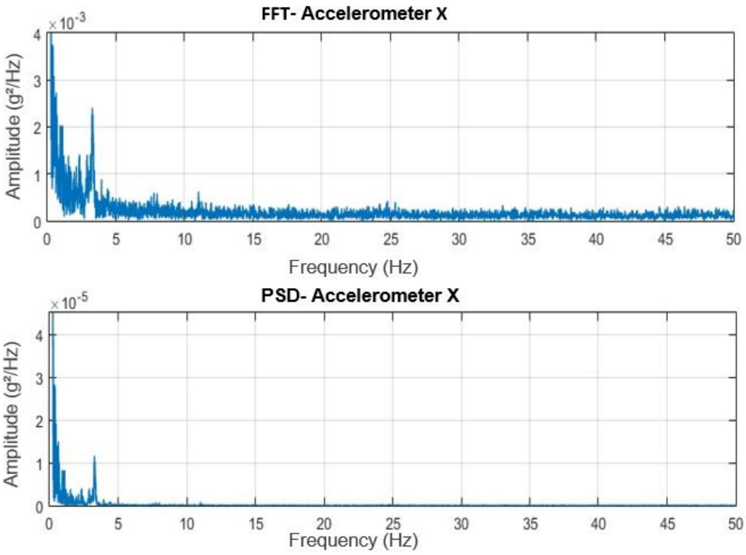

Figure 7: FFT and PSD free vibration from Lorenzetti 242 kV

Figure 8 presents the frequency profile for the moment after the coupling of the main contact blade with the fixed contact. It is noted that the frequencies on this axis of the Cartesian plane, in the direction that will be the excitation with the vibrator motor, has its greatest amplitude below 5 Hz.

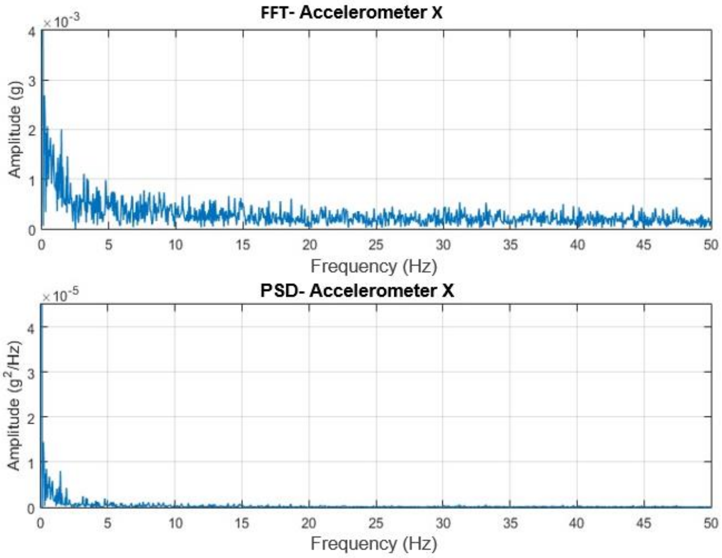

Figure 8: FFT and PSD Lorenzetti 242 kV free vibration coupling

4.4 Forced vibration test under harmonic vibration

In this section the data concerning the deformation of the high voltage switch's transmission tube will be presented, as well as the frequencies that occur during the forced vibration test for the Lorenzetti 242 kV switch. Among all monitored deformation points in this switch, the largest deformation of the structure was in the transmission tube for both vibration models tested. Figure 9 shows the signal of deformation incident at the point of greatest deformation. It is clear from the signal that the moment of greatest deformation, 71,46 µm/m, occurred at the moment of opening of the switch, at which time the blade of the main contact moved in the direction of exit of the fixed contact. When the switch was in the open position, the transmission tube still showed some deformation, since the kinematic chain was designed so that the transmission tube was a kind of backup to the system designed to hold the main contact blade in vertical position.

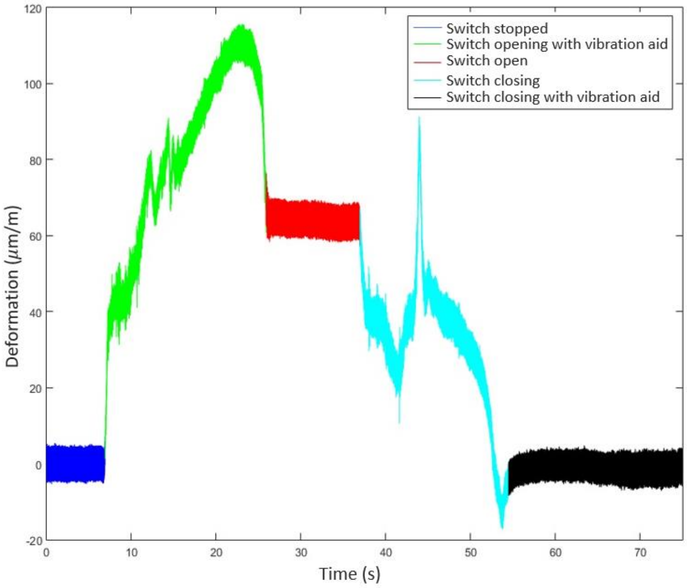

Figure 9: Deformation of transmission tube under harmonic vibration, on Lorenzetti 242 kV switch

The mean value of the 100 cycles, 10 for each cycle can be seen in table 4.

Table 4: Mechanical Tension Data and Deformation for Forced Vibration in the Transmission Tube

	1º	**2º**	**3º**	**4º**	**5º**	**6º**	**7º**	**8º**	**9º**	**10º**
Deformation (µm/m)	71,46	64,99	64,96	49,90	65,93	49,33	63,78	64,23	68,42	69,79
Mechanical Tension (MPa)	14,29	12,99	12,99	9,98	13,18	9,86	12,75	12,84	13,68	13,95

The tests in this section were performed according to the eccentric mass and excitation frequency parameters as noted above (2.2 kg and 6.8 Hz respectively). Figure 10 shows the acceleration signature in which the main contact blade was subjected during forced harmonic excitation. The acceleration incident on the main contact blade is found to be practically the same as that during free vibration testing.

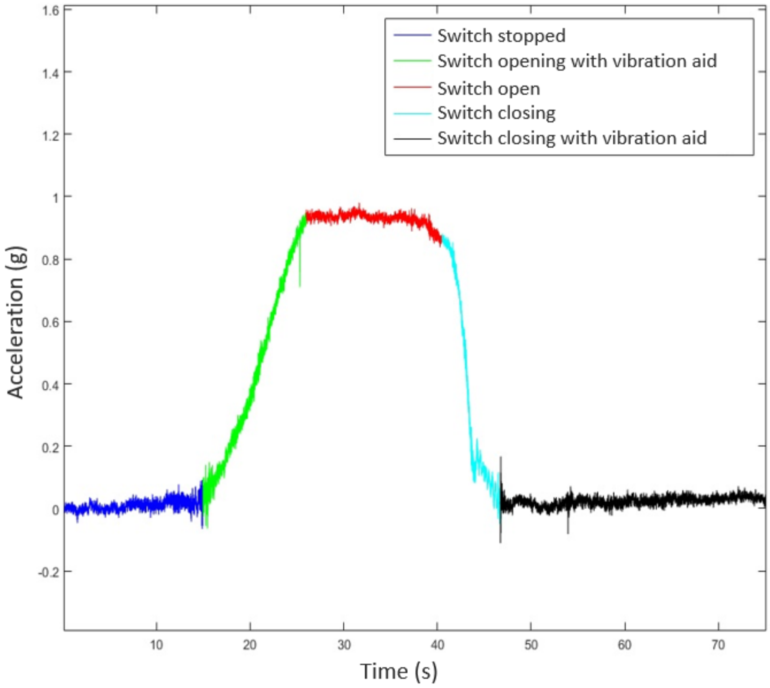

Figure 10: Incident accelerations of forced vibration on Lorenzetti 242 kV switch under harmonic excitation

Figure 11 presents the postprocessing of acceleration data.

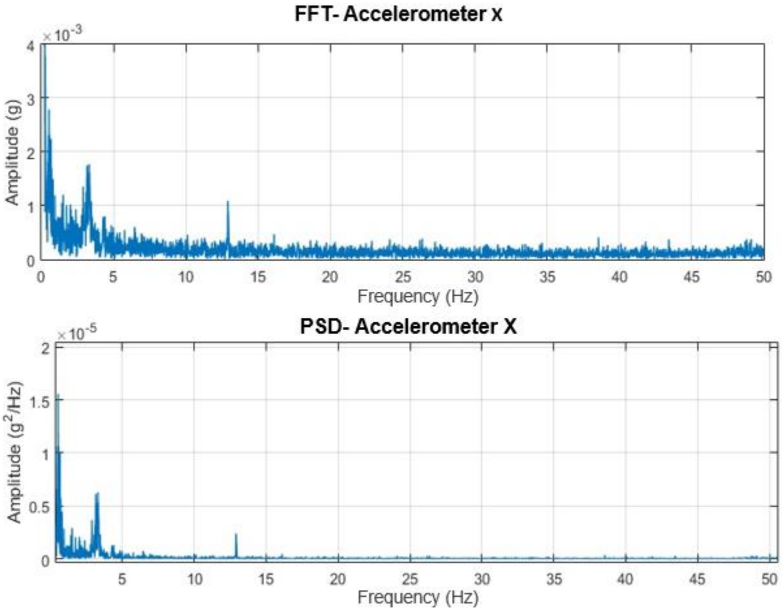

Figure 11: FFT and PSD of Lorenzetti 242 kV signal under harmonic vibration

As well as free vibration, there are some relatively low frequency components, between 1 Hz and 5 Hz. However, there is the 13 Hz component that was not present in the other tests. In order to better investigate the incident frequencies in the high voltage switches, the signal collected through the accelerometer was windowed.

In this process, we sought to collect the frequencies at the instant following the impact of the main contact blade entry on the fixed contact of the switch. In the Figure 12 there is the frequency signal at the instant described above. Interestingly, in the frequency profile, the 13 Hz component remained present after impact, but its amplitude was greater than twice its initial value.

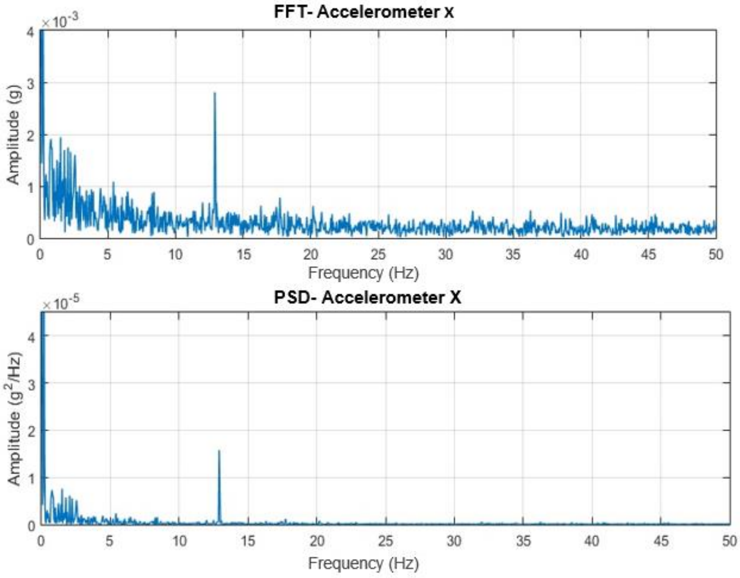

Figure 12: FFT and PSD of Lorenzetti 242 kV signal, under harmonic vibration

4.5 Hypothesis test for free vibration and vibration under harmonic excitation

After determining the 95% confidence interval, the difference between population mean of the collected data was analyzed. Then it was determined whether the statistical differences are significant. It is noteworthy that in all tests the presence of atypical values (outliers) was analyzed through boxplot graphs. Observing the presence of such values, they were eventually deleted before subsequent inference. Thus, it is expected to ensure greater reliability compared to the final conclusions of the tests.

4.6 Lorenzetti 242 kV switch

Then, Table 3 presents the data for the Lorenzetti 242 kV switch, obtained through the mean comparison test, t-test, comparing free vibration and vibration under harmonic excitation.

As pointed out in the section before, it is important that the deformation data of each point is compared with the flow limit material of each point, so that it is checked whether the deformation is within the elastic limit of the material. Through the average deformation of the monitored points, it was found that the point of greatest deformation, transmission tube, presented equality when compared the models of tested vibration, free vibration and forced vibration under harmonic excitation. It is also pertinent to point out that all deformations in the structure were within the elastic regime of the materials, including in the transmission tube.

Table 3: Results of the Lorenzetti 242 kV Hypothesis Test

Point Description	Null Hypothesis (H_0)	Alternative Hypothesis (H_1)
Main Contact		X
Middle blade stem middle		X
Main blade base		X
Connection terminal		X
Main blade rotating base		X
Transmission tube	X	
Fixed porcelain column	X	
Support column		X

4. Conclusion

In this research, the emphasis was on the experimental basis in view of the impacts on the power supply when failures in high voltage switches occur. However, despite the constant investments in research and development in the electricity sector, there is still no concrete answer that meets the diversity of high voltage switches present in the generation, distribution and transmission system.

Therefore, as a conclusion, this study makes the following notes:

- Despite ANEEL's 30-year payback guidance for substation equipment, they are not replaced by more modern equipment;
- Some electrical components were defective and failed during preliminary testing;
- Some mechanical components have defects and failures arising from defects in electrical components;
- Standards for mechanical durability testing are unclear regarding the variables to be monitored;
- Both disconnect switches tested in the preliminary tests do not meet the mechanical durability requirements of [5] and [6];
- The methodology developed for the definition of the test procedure proved useful, due to the points and insights for standardization and suggestion of tests for normative entities;
- The highest torque required for switch operation occurs at the moment of disconnection;
- It is found that even if there is a difference between free vibration and vibration under forced harmonic excitation at the point of greatest deformation for the high voltage switch, the deformation is within the elastic regime of the material;

- Closing maneuvers presented better quality when the maneuver was under forced harmonic vibration excitation;

- The fasteners of the support structures of both disconnectors showed no loosening or torque variation with the application of forced vibration under harmonic excitation.

References

[1] ROCHA, L. F., Implementação de um Sistema para Manobra de Seccionadores de Alta Tensão Visando seu Processo de Automação. Dissertação (Mestrado em Projeto e Processos de Fabricação) – Universidade de Passo Fundo, Passo Fundo, 2014.

[2] ROCHA, L. F., Inventor; CEEE, Cessionário; FUPF, Cessionário. Dispositivo de Automação de Seccionador de Alta Tensão. Brasil BR 10 2013 020198 7. Aug 08, 2013.

[3] Peter Rubie, J. R. Australia/Queensland Patent No. US6889820 B2, 2001.

[4] GOETTEMS, F. S.; DE BRAGA, R. M.; REGULY, A.; Controle de pré - carga em parafusos: Correlação entre o método do torque e do alongamento medido por ultrasson. Tecnol, Metal, Mater, Miner. São Paulo, 2017.

[5] ABNT NBR IEC 62271-102 Equipamentos de alta tensão parte 102: Seccionadores e chaves de aterramento. 2006.

[6] ABNT NBR IEC 60694 Especificações comuns para normas de equipamentos de manobra e alta-tensão e mecanismos de comando. 2006.

[7] ABNT NBR 7571. Seccionadores – Características técnicas e dimensionais, 1985.

[8] SETTI, A.; DARONCH, J.W.; DALLA MARIA, L.; MARTINELLI, P. V.; HERZOG, J.V.B; RECH, M.; ISRAEL, C.L.; DA ROCHA, L. Impacto da Vibração Mecânica em Parafusos de Seccionadores Lorenzetti 242 kV e BMKU – 40A. XVII ERIAC, Foz do Iguaçu, 2019.