RESULTS OF ANEEL GGT SYSTEM AS A RESPONSIVE REGULATION TOOL FOR TRANSMISSION LINES AGAINST WILDFIRES

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ABSTRACT

The Geospatial Transmission Management System (GGT System) was launched in 2017 and consists of a tool developed by the Brazilian Electricity Regulatory Agency (ANEEL) that aims to monitor, through remote sensing and use of Artificial Intelligence (*deep learning*), the maintenance carried out by electricity transmission concessionaires in all spans of Transmission Lines (TLs) located in regions with historical incidences of wildfires. The purpose is that the quantities of forced shutdowns due to wildfires are reduced mainly in the TLs monitored by the GGT System, seeking to ensure high levels of safety and reliability in the operation of the National Electric System.

Considering the 51 TLs that had a history of shutdowns due to wildfires in the period between 2013 and 2017 and that started to be monitored from 2017, the year the GGT System started operating, and comparing their performances in this type of cause with the period between 2017 and 2021, it was found that the number of shutdowns in the first period, which had an average annual growth rate of 47%, started to show, in the second period, an average annual decrease rate of 18% (reduction of 65 percentage points). When comparing in 2021 the absolute value projected by the trend line prior to the beginning of the GGT System with the number of shutdowns due to wildfires recorded that year, it appears that the absolute reduction was 83%.

Between 2021 and 2022, a very relevant fact was also found. The absolute number of shutdowns due to wildfires in the group of 51 TLs monitored by the GGT System from 2017 onwards decreased by 29%, while the number of hot spots registered by the National Institute for Space Research (INPE) at

a distance of up to 1 km from the same TLs increased by 6%. In the TLs that had a history of shutdowns due to wildfires in the period between 2013 and 2017, but which were not included in the monitoring of the GGT System in 2017, which total a group of 307 TLs distributed throughout Brazil, the absolute number of shutdowns due to wildfires decreased by 68% between 2021 and 2022, while the number of hot spots registered by INPE throughout Brazil increased by 9%.

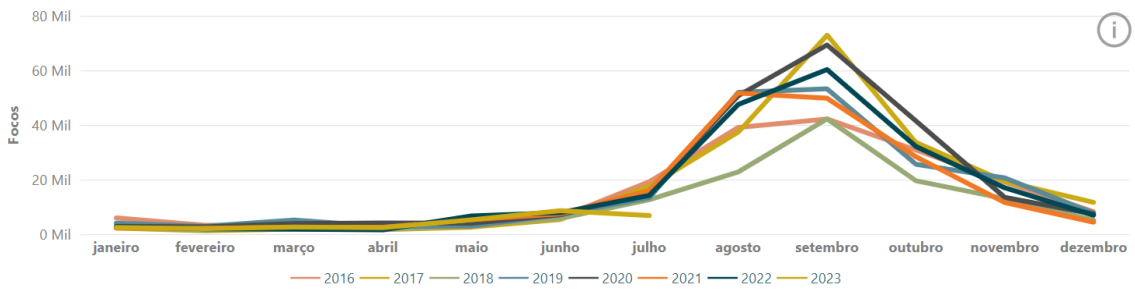
In view of the findings presented in this summary and throughout this article, it is concluded that the GGT System has served as an inducer of improvements for the Transmission Companies to promote improvements in their processes for managing the maintenance of the safety lanes of the TLs under their concessions, improvements whose effects began to be perceived in the performances in the face of burning of the TLs, monitored and not monitored by the GGT System, from the moment the monitoring actions promoted by ANEEL/SFT were intensified. Thus, the GGT System presents itself as a very effective Responsive Regulation tool, making use of innovative geoprocessing technologies that seek the rational use of public resources to increase the safety of the operation of the National Electric System.

KEYWORDS: GGT System, Maintenance of Transmission Lines, Remote Sensing, Geoprocessing, Artificial Intelligence, *Deep learning*, *Machine learning*, Wildfires, Fires, NDVI, Analytical Intelligence, ArcGIS, Responsive Regulation, Monitoring.

INTRODUCTION/PURPOSES

The occurrence of wildfires is a reality that occurs in several regions of Brazil. Especially in the North, Midwest, part of the Southeast and in the interior of the Northeast, these events are intensified during the dry season of the year, which encompasses the period from July to December. It is in these regions where there are important sets of TLs, called Regional Interconnections, responsible for the transmission of much of the electricity consumed in the country. Figure 1 shows the monthly distribution of hot spots recorded by INPE throughout Brazil over the last 8 years.

Figure 1 – Monthly distribution of hot spots between 2016 and 2023 (Source: INPE)



The incidence of wildfires in the safety lanes of the Regional Interconnections represents a serious risk of forced shutdowns of these TLs, a situation that, depending on the conditions of the electrical system at the moment, can cause blackouts with serious consequences for the entire country. This is what happened on August 28, 2013, when a major fire reached the safety range of the 500 kV Ribeiro Gonçalves / São João do Piauí TL, part of the North/Northeast Interconnection (N/NE), and caused the shutdown of the two circuits of this TL simultaneously, causing a blackout throughout the Northeast region of Brazil.

In order to mitigate the risks of recurrence of major occurrences caused by wildfires in electricity transmission facilities, ANEEL/SFT started to invest in new technologies to improve TL inspection techniques, resulting in the development of the GGT System.

The purposes of this work are to present the results verified in the performances of the TLs, monitored and not monitored by the GGT System, and to present the technological innovations implemented and under implementation in this important Responsive Regulation tool.

MATERIAL / METHODOLOGY

The methodology adopted in the monitoring carried out by the GGT System consists of processing different data from different sources, such as: XML files sent monthly by the Transmission Companies to ANEEL containing information on dates of inspections and plant suppression (cleaning) carried out in each of the spans of the TLs monitored by the GGT System; Photographic evidence of inspection and cleaning activities carried out in the field and sent to ANEEL by the Transmission Companies through forms developed specifically for the GGT System in the Survey 123 mobile application of the ArcGis platform; Data referring to dates, times and locations of forced shutdowns due to wildfires monitored in real time by the National Electric System Operator (ONS) through the Integrated Disturbance Registration System (SIPER/ONS); Images obtained from the Sentinel 2 satellite collection of the *European Space Agency* (ESA); Geographic data of heat sources mapped by INPE throughout Brazil.

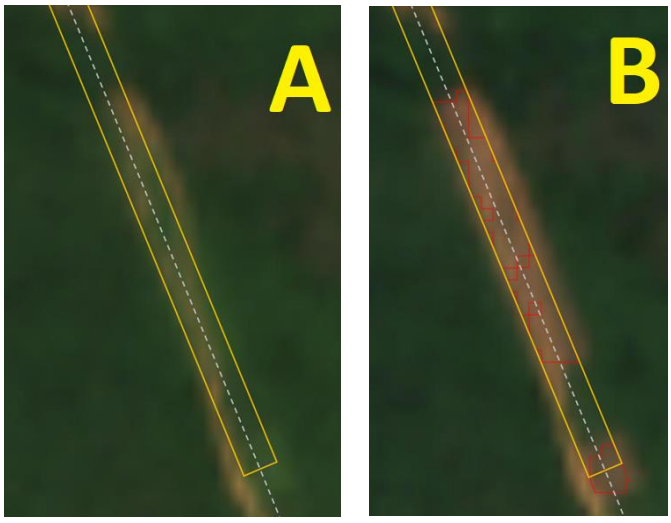
Based on the dates informed by the Transmission Companies regarding the performance of plant suppression in the spans of the monitored TLs, the GGT System automatically detects the exact geographical locations of these spans and searches satellite images before and after the informed dates to make comparisons between the images using the vegetation index *Normalized Difference Vegetation Index* (NDVI). The purpose is to detect significant changes in the vegetation within the analyzed spans, validating, or not, the cleanings carried out by the Transmission Companies.

Figure 2 illustrates a case recorded in a 234 km TL monitored by the GGT System located in the state of Piauí. As informed in the XML file sent to ANEEL by the Transmission Company holding the concession of this TL, cleaning was carried out in some spans on March 8, 2022. Based on this

information, the GGT System automatically searched the Sentinel 2 satellite database for images without cloud cover before and after the informed date of cleaning and applied the NDVI. Figure 3 shows the analyzed images referring to span 19 of this TL. It is observed that, when comparing image A with image B, which were recorded on January 25, 2022, and April 19, 2022, respectively, it is possible to verify that there were significant changes in the colorations of the pixels located within the span, denoting that in fact there was suppression of the vegetation in the span at some point in the period between both images. Thus, the GGT System classified this span as validated in relation to cleaning.

Figure 2 – TL monitored by the GGT System in the state of Piauí.

Figure 3 – Sentinel 2 satellite images of span 19 recorded on 1/25/2022 (A) and 4/19/2022 (B)



If the dates of the cleaning informed by the Transmission Companies are not validated by the GGT or information is found that offers potential risks to the safety of the operation of the TLs, such as, for example, significant amounts of cleaning of spans foreseen during the critical period of wildfires, preventive alerts are sent to the Transmission Companies in order to seek self-regulation of the problems, so that they can timely review their maintenance plans in order to finalize the cleaning of the spans by July at the latest. If the GGT System does not confirm that in fact there was a timely regularization of the problems and finds that there were shutdowns of the TLs due to wildfires in spans that have not received adequate maintenance, reports are issued to the inspection teams of ANEEL/SFT recommending the referral of cases to the later stages of the Responsive Regulation process, which may result in the agreement of results plans between ANEEL and the Transmission Companies or in inspection actions that will eventually result in administrative sanctions.

Another important feature of the GGT System is the automatic detection, through the Artificial Intelligence (AI) technique called *deep learning*, of burn scars that intercepted the safety lanes and caused forced shutdowns of the monitored TLs. All spans affected by the wildfires are highlighted and reports are issued containing diagnoses of the maintenance situations of these spans, subsidizing the inspection processes.

Figure 4 illustrates the case of a wildfire that caused the shutdown of a TL monitored by the GGT System. Based on the data automatically consumed from the SIPER/ONS system, it was found that the TL suffered a forced shutdown on 09/22/2022 at 3:43 pm and that the shutdown took place in a span located 153 km from one of the terminal substations. With this information, the AI of the GGT System was able to delimit the polygon of influence of the burn scar and determine all the spans that were affected in the occurrence. Then, all available information on the maintenance of these spans was searched in the GGT System database, such as expected and performed dates of the last inspections and cleanings, information on validations by the NDVI of the cleanings carried out in these spans and field photographic evidence sent by the Transmission Company through the Survey 123 mobile application. Figure 5 presents examples of photographic evidence sent by the Transmission Company regarding the inspection and cleaning activities carried out in one of the spans affected by the wildfire, which were used by the inspection teams of ANEEL/SFT during the analysis of the case. Both pieces of evidence were recorded before the wildfire occurred.

Figure 4 – Result produced by the Artificial Intelligence of the GGT System in the automatic detection of the burn scar and the affected spans.

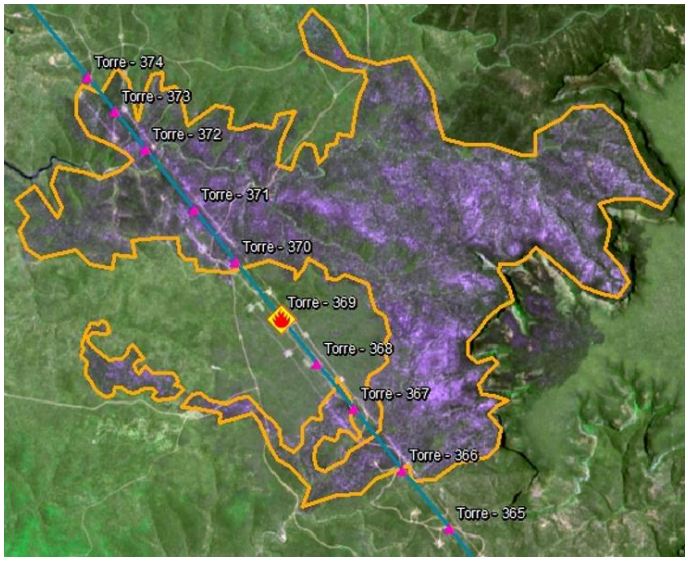


Figure 5 – Photographic evidence of inspection and cleaning activities sent by the Transmission Company to the GGT System through the Survey 123 mobile application.

RESULTS AND DISCUSSION

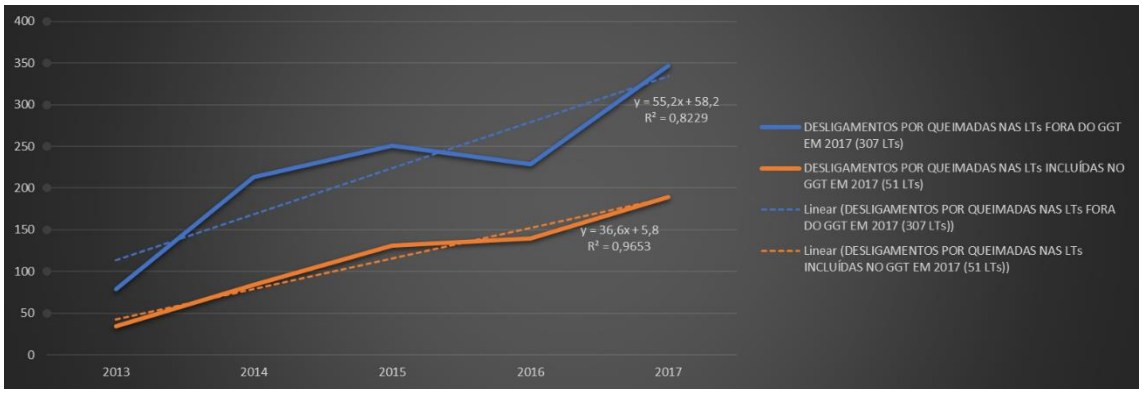
Since the beginning of the operation of the GGT System in 2017, dozens of preventive interactions have been carried out with the Transmission Companies in order to present the findings made, the preventive alerts issued and demand improvements in the TLs safety lane maintenance management processes. Some inspection actions were also carried out that resulted in the application of penalties. In addition, 6 seminars were promoted in order to share, among the Sectoral Agents, the verified results, good practices and technological innovations that are constantly being incorporated into the GGT System.

TLs PERFORMANCES BEFORE AND AFTER OPERATION OF THE GGT SYSTEM

In the period between 2013 and 2017, there were 358 LTs in operation in the Basic Network[1] that presented at least one forced shutdown caused by wildfires. These TLs suffered a total of 1697 shutdowns due to wildfires in this period. For the purposes of this study, this universe of TLs was divided into two groups. LTs INCLUDED IN GGT IN 2017: It includes 51 LTs that were included in the monitoring of the GGT System right at the beginning of the system's operation in 2017; LTs OUTSIDE the GGT IN 2017: It includes the other 307 TLs in the universe that were not included in the monitoring of the GGT System in 2017. It is noteworthy that the new TLs that originated from the sectioning of the TLs object of this study were also considered in each group and had their forced shutdowns due to computed wildfires, since they are, in practice, the same original TLs.

Analyzing the curves of forced shutdowns due to wildfires of the two groups of TLs, it is possible to observe that both had increasing trends of shutdowns in the period between 2013 and 2017, as shown in Figure 6 . The TLs group INCLUDED IN THE GGT IN 2017 presented an average annual rate of increase in shutdowns due to wildfires of 47% and the TLs group OUTSIDE THE GGT IN 2017 presented a rate of 31%. It is also observed that the models drawn for both groups have high accuracies (R^2= 0.9653 and R^2=0.8229, respectively), demonstrating strong adherence between the real data and the trend lines.

Figure 6 – Forced shutdowns due to wildfires in the period between 2013 and 2017 in the two groups of TLs object of this study. The group INCLUDED IN THE GGT IN 2017 is orange and the group OUTSIDE THE GGT IN 2017 is blue.

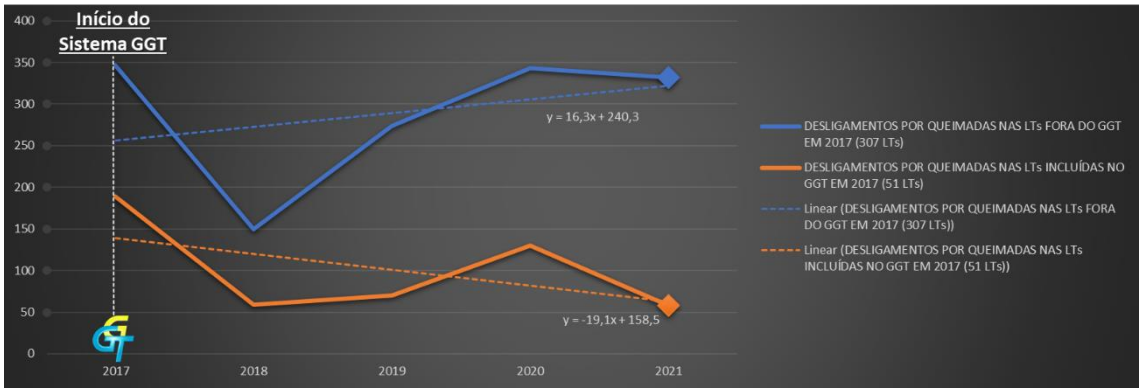


Between 2017, the year the GGT System started operating, and 2021, there were very significant reductions in the average annual rates of shutdowns due to wildfires in both groups. As shown in Figure 7 , the LTs group INCLUDED IN THE GGT IN 2017 was the one that presented the most significant result, registering an average annual rate of -18% (reduction of 65 percentage points compared to the average annual rate of the period between 2013 and 2017), with its trend line even becoming decreasing in the period. The LTs group OUTSIDE the GGT IN 2017 recorded an average

[1] TLs throughout Brazil with voltage levels equal to or greater than 230 kV.

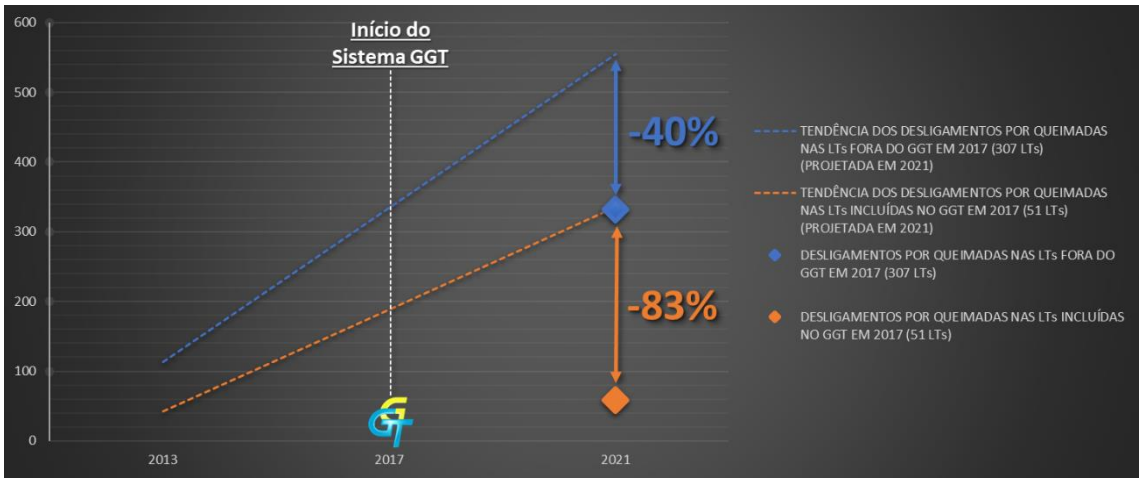
annual growth rate of 6% between 2017 and 2021, representing a reduction of 26 percentage points when compared to the average annual rate for the period between 2013 and 2017.

Figure 7 – Forced shutdowns due to wildfires in the period between 2017 and 2021 in the TLs object of this study, with emphasis on the year of start of operation of the GGT System. The group INCLUDED IN THE GGT IN 2017 is orange and the group OUTSIDE THE GGT IN 2017 is blue.



Projected in 2021 the trend lines presented in Figure 6 and comparing the respective estimated values of shutdowns due to wildfires with the values actually recorded in both groups, it can be seen in Figure 8 that there was an 83% reduction in the absolute values of shutdowns due to wildfires of the LTs group INCLUDED IN THE GGT in 2017 and 40% in the LTs group OUTSIDE the GGT in 2017, confirming the effectiveness of the Responsive Regulation actions implemented by ANEEL/SFT from 2017.

Figure 8 – Percentage reductions in shutdowns due to wildfires (Trends versus Measurements in 2021). The group INCLUDED IN THE GGT IN 2017 is orange and the group OUTSIDE THE GGT IN 2017 is blue.



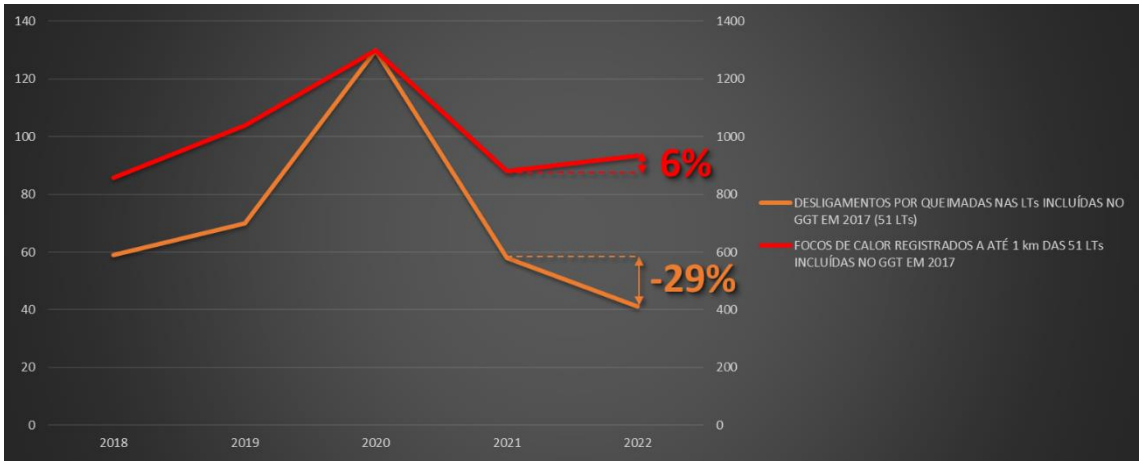
TL PERFORMANCES IN 2022

As of 2021, ANEEL/SFT intensified the interaction with the Transmission Companies holding TL concessions monitored by the GGT System. 36 Official Letters containing preventive alerts were sent

and 19 specific meetings were held with the Transmission Companies on the findings obtained from the GGT System data, in addition to 25 LTs being indicated to have their performances in the face of wildfires analyzed in greater detail by the other inspection teams of ANEEL/SFT.

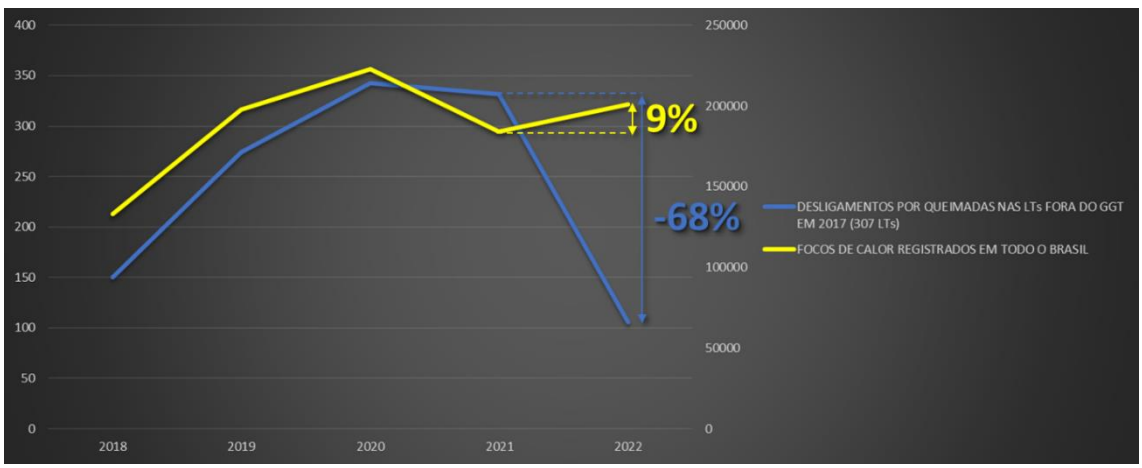
In 2022, it was found that the number of forced shutdowns due to wildfires in the TLs group INCLUDED IN THE GGT IN 2017 continued to decrease, with a reduction of 29% compared to the amount recorded in 2021. Interestingly, the number of hot spots recorded by INPE at a distance of up to 1 km from these TLs increased by 6% between 2021 and 2022. This divergence is presented in Figure 9 .

Figure 9 – Comparison between quantities of hot spots close to the 51 LTs included in the GGT in 2017 and shutdowns due to wildfires of the LTs group INCLUDED IN the GGT in 2017. Shutdowns are shown in orange and hot spots in red.



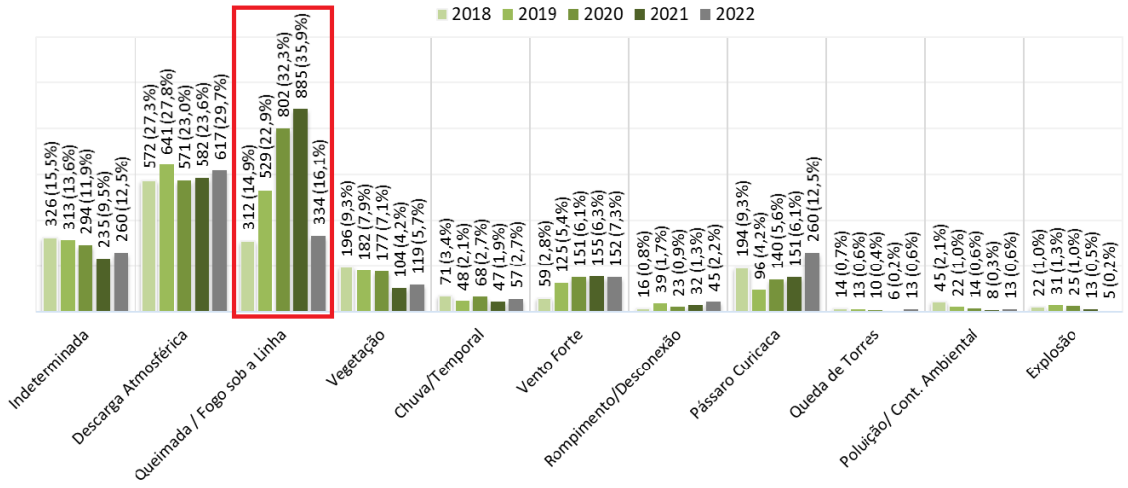
The same divergent behavior could be observed, in an even more expressive way, when comparing the curves of forced shutdowns due to wildfires in the LTs group OUTSIDE the GGT in 2017 and of hot spots recorded by INPE throughout Brazil, according to Figure 10.

Figure 10 – Comparison between amounts of hot spots throughout Brazil and shutdowns due to wildfires of the LTs group OUTSIDE the GGT IN 2017. Shutdowns are shown in blue and hot spots in yellow.



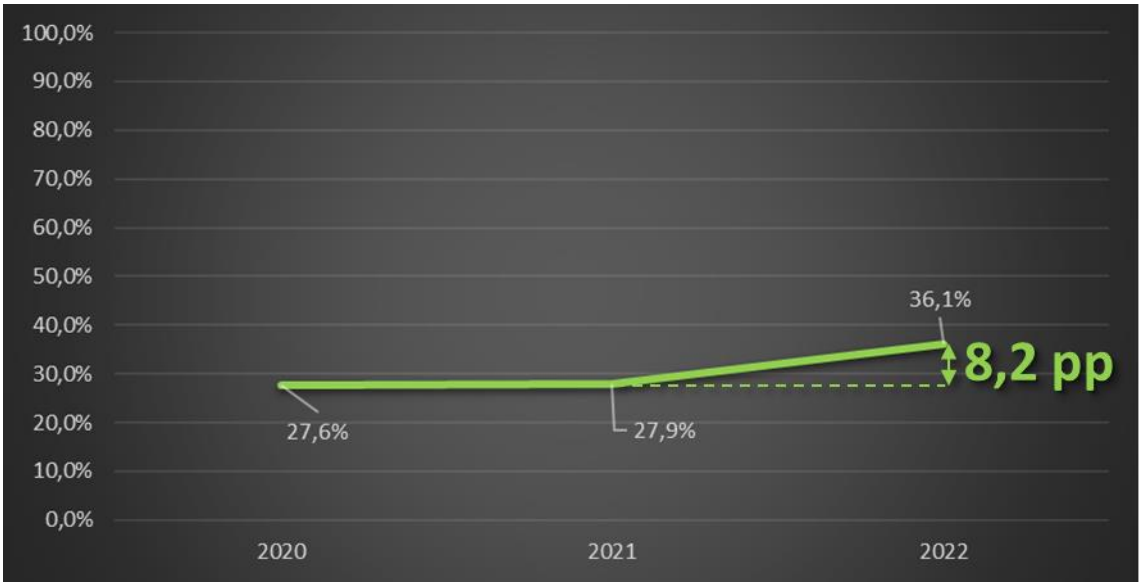
According to the "STATISTICAL ANALYSIS REPORT OF FORCED SHUTDOWNS FOR THE YEAR 2022" issued by ONS, the number of shutdowns due to wildfires registered in all TLs of the Basic Network went from 885 in 2021 to 334 in 2022, which represents a reduction of 62%. In the same period, there were no significant increases in the other causes of forced shutdowns registered by the ONS, showing that there was no migration of shutdowns to other causes, such as, for example, Undetermined Cause, but that in fact there was an effective reduction in shutdowns due to wildfires, according to Figure 11 .

Figure 11 – Main causes of shutdowns of internal origin in the years 2018 to 2022 – Basic Network (Source: ONS - STATISTICAL ANALYSIS REPORT OF FORCED SHUTDOWNS FOR THE YEAR 2022). The causes, shown from left to right, are: Indefinite; Atmospheric Discharge; Burn/Fire under the line; Vegetation; Rain/thunderstorm; Strong wind; Disruption/disconnection; Curicaca Bird; Fall of Towers; Pollution/Environmental contamination; Explosion



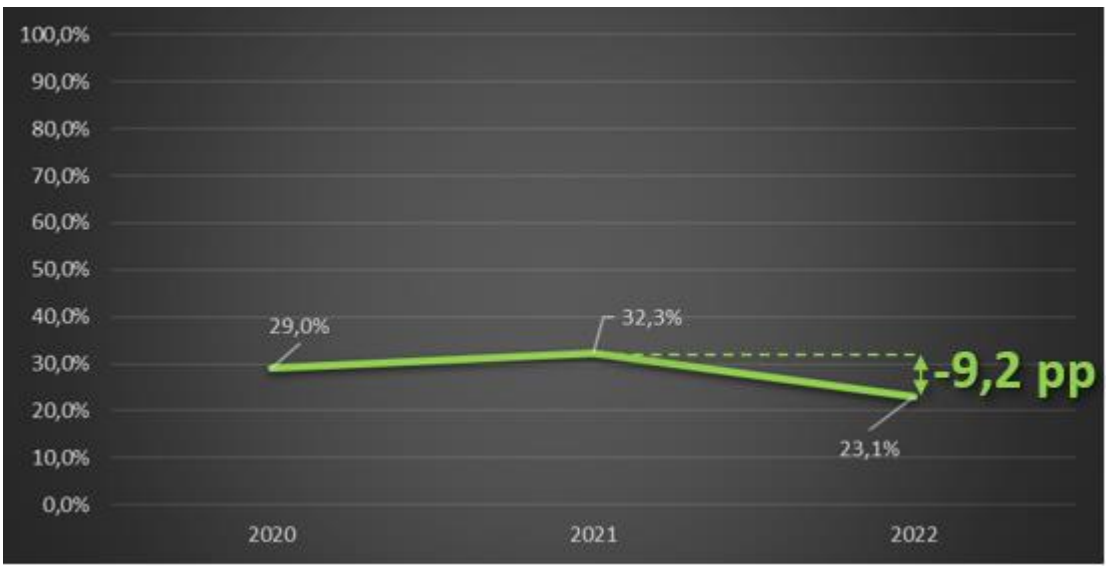
Analyzing the data of the TLs monitored by the GGT System, it is possible to identify some factors that probably contributed to the great reduction in the amounts of shutdowns due to wildfires. Figure 12 shows the evolution of the percentage of spans that had at least one cleaning performed since the beginning of the GGT System, according to the information provided by the transmission Companies via XML. It was found that there was an increase of 8.2 percentage points between 2021 and 2022, showing that a significant number of spans that normally did not receive cleaning underwent cleaning in 2022. Considering that in 2022 the GGT System monitored a total of 77,214 spans, which represented approximately 38,000 km of TLs, it is concluded that, in 2022, 6,357 new spans were cleaned, equivalent to about 3,200 km of TLs.

Figure 12 – Percentages of Spans with at least one cleaning performed since the beginning of the GGT System in relation to the total spans monitored in each year.



Comparing the percentages of spans that were cleaned in 2021 and 2022 in relation to all spans monitored by the GGT System in 2022, there was a reduction of 9.2 percentage points in the period, which is equivalent to 7,104 spans and about 3,500 km of TLs, as shown in Figure 13. This shows that there was a significant reduction in the total amount of spans that underwent cleaning when comparing the two years, denoting that the maintenance costs of the Transmission Companies were reduced in 2022.

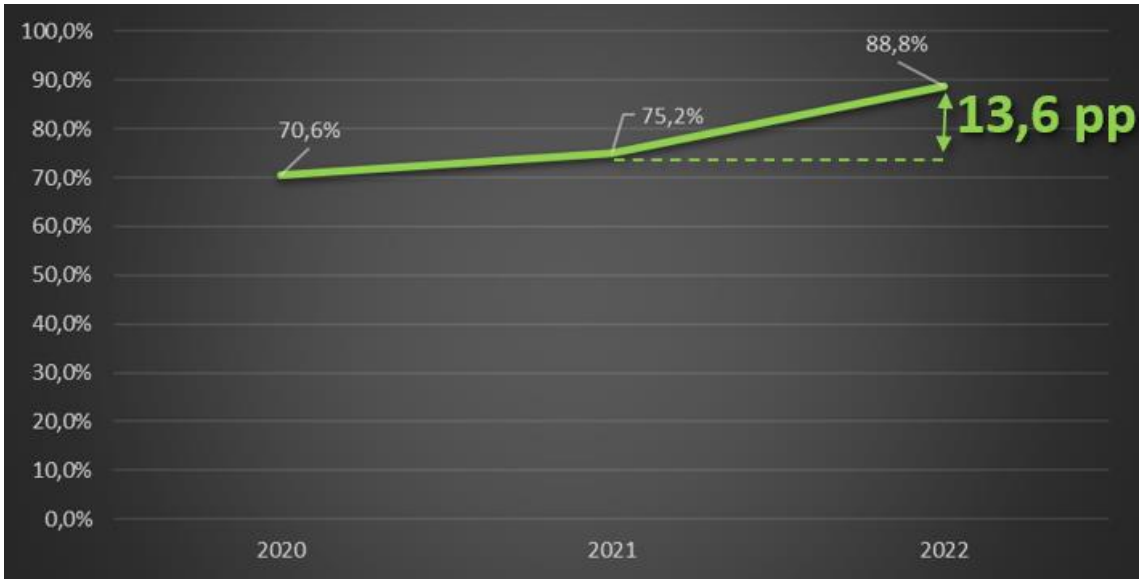
Figure 13 – Percentages of spans that were cleaned in relation to the total spans monitored by the GGT System in each year.



When comparing the percentages of spans that were cleaned until July in relation to the total spans that were cleaned in 2021 and 2022, there was an increase of 13.6 percentage points, which is

equivalent to 2,425 spans and about 1,200 km of TLs, showing that there was a significant increase in the number of spans that were cleaned before the beginning of the critical burning period, as shown in Figure 14 .

Figure 14 – Percentages of spans that were cleaned up to July in relation to the total spans that were cleaned each year.



CONCLUSION

Given the data presented, it is possible to reach some conclusions: In 2022, the transmission companies concentrated much of their cleaning activities in spans that normally did not receive annual cleaning and reduced the total quantities of clean spans, denoting a probable improvement in the quality and assertiveness of the inspections carried out to map the most critical spans with a reduction in maintenance costs. The transmission companies also committed to carrying out the cleanups by July, that is, before the start of the critical burning period. These seem to have been the right management strategies since the TLs were more “immune” to wildfires in 2022. Another relevant fact was that the positive results were not restricted to the TLs monitored by the GGT System, showing that the aforementioned actions had effects on all TLs in Brazil.

Finally, it is concluded that the GGT System has served, since the beginning of its operation in 2017, as an inducer of improvements for the Transmission Companies to promote improvements in their processes for managing the maintenance of the safety lanes of the TLs under their concessions, improvements whose effects began to be perceived in the performances of the TLs throughout Brazil, monitored and not monitored by the GGT System, from the moment the monitoring actions promoted by ANEEL/SFT were intensified. Thus, the GGT System presents itself as a very effective Responsive Regulation tool, making use of innovative geoprocessing technologies that seek the rational use of public resources to increase the safety of the operation of the Brazilian Electric System.

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