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SUPPORT SYSTEM FOR OUTAGES CAUSED BY LIGHTNING EVALUATION (SAAD)

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1 INTRODUCTION

FURNAS [1] was founded in 1957, and nowadays is responsible for supplying regions where live 51% of the Brazilian people. FURNAS' role in some States supplying is: 97% in Distrito Federal, 92% in Rio de Janeiro; 91% in Mato Grosso; 81% in Espírito Santo; 61% in Goiás; 58% in São Paulo; 45% in Minas Gerais and 16% in Tocantins.

These States represent a strategic area of the Country where are installed most of the industries and factories. Due to its large extension, in this area it is found a vast climatologic variation in which FURNAS has faced and overcome many of the challenges that it represents.

FURNAS' complex is composed by 10 hydroelectric plants, 2 thermal plants, which represent an installed generating capacity of 9,467 MW, besides 46 substations and 19,277.5 kilometers of transmission lines. A map of FURNAS generation and transmission system can be seen in Figure 1.

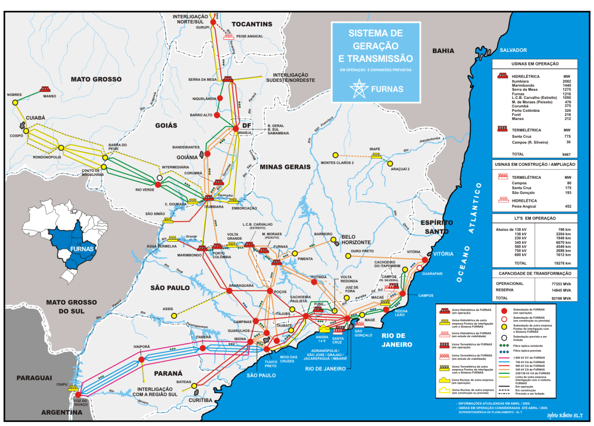

Figure 1: FURNAS Generation and Transmission Map

FURNAS is one of the RINDAT [2] (National Integrated Network of Lightning Detection) members. This lightning location system is the third biggest in the world and nowadays is composed by 37 sensors, covering most of the Brazilian territory, as can be seen on Figure 2.

Figure 2: RINDAT Sensors Location Map (Status in July 2007)

With investments in new projects and the integration of new partners, RINDAT is expected to have a total number of 63 sensors in 2008 and it will be renamed BrasilDAT.

One of the main reasons, which motivated FURNAS to develop a system to support the analysis of its transmission lines performances, considering lightning, was the difficulty in classifying this kind of outages quickly and reliably, using RINDAT (National Integrated Network of Lightning Detection) already available data.

Because of that, in its Research and Development Plan, FURNAS firmed an agreement with INPE (Instituto Nacional de Pesquisas Espaciais) to develop a customized system of lightning data evaluation, considering the detection efficiency of the lightning location system in different regions and also the statistical variations of different types of lightning.

2 SAAD

The base map used by SAAD for all the lightning outage analysis is the one available in FURNAS intranet, called GISFURNAS, where all the transmission lines are geo referenced, tower by tower. Besides that, SAAD was developed in a way to access this information straight in FURNAS database, so that any update in the transmission system would be automatically updated in SAAD.

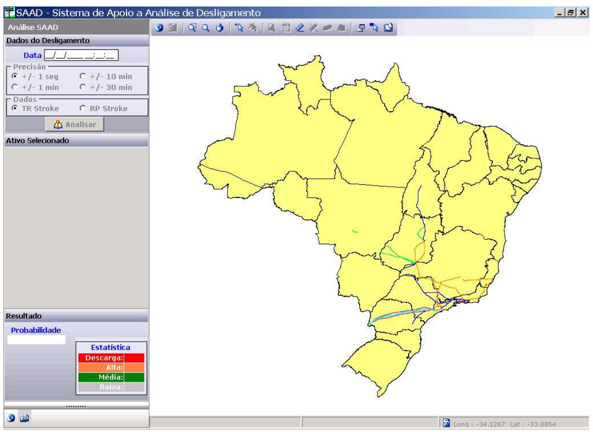

Figure 3: SAAD main screen

SAAD also accesses not only FURNAS real time lightning data, provided by RINDAT, but also the historical data, which have been reprocessed during the project of research and development. Nowadays, the new real time data is reprocessed every day and then it feeds the historical data.

As SAAD was developed to make the outage analysis easier, quicker, more simple and reliable, with less subjectivity, it allows the user to input the transmission line that has tripped out, by selecting it at the map, and the date and time of the outage. Even the precision of the outage time is taken into account during the evaluation, once the user is able to input one among the following options: ± 1 second, ± 1 minute, ± 10 minutes or ± 30 minutes.

After that, the analysis can be loaded and it will make an algorithm run considering the detection efficiency of the lightning location system in the specific region, where the transmission line is located and also the statistical variation of different types of lightning in that region.

This algorithm will check all the data involved and the output of the analysis, which means the cause of the outage, will be one of the following results: No Lightning, Lightning Low Probability, Lightning Medium Probability or Lightning High Probability, as shown in the next four figures, respectively.

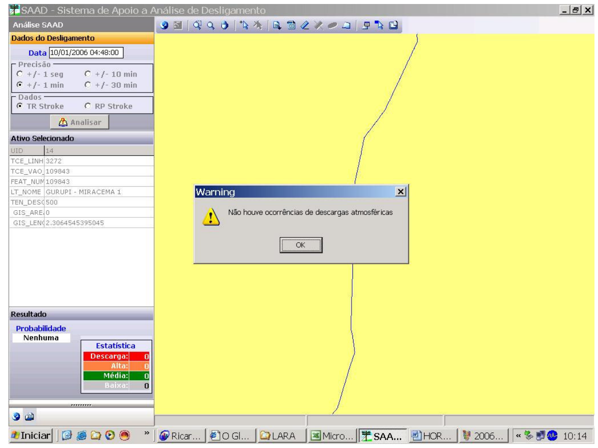

Figure 4: Example of “No Lightning” Result

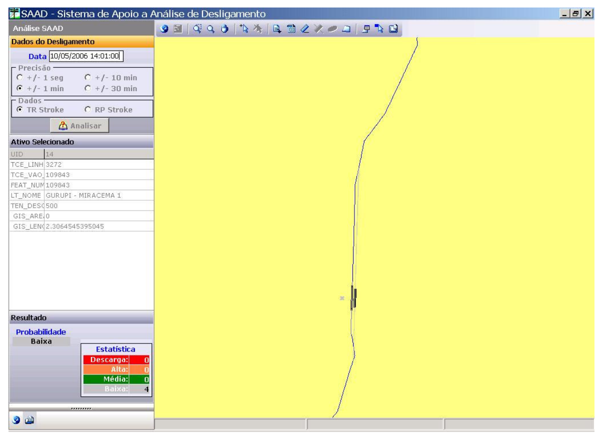

Figure 5: Example of “Low Probability Lightning” Result

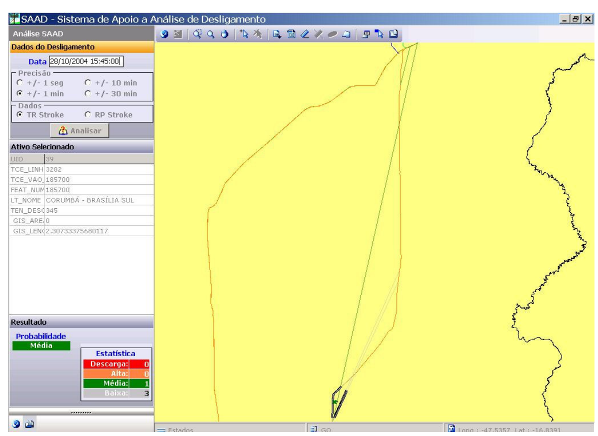

Figure 6: Example of “Medium Probability Lightning” Result

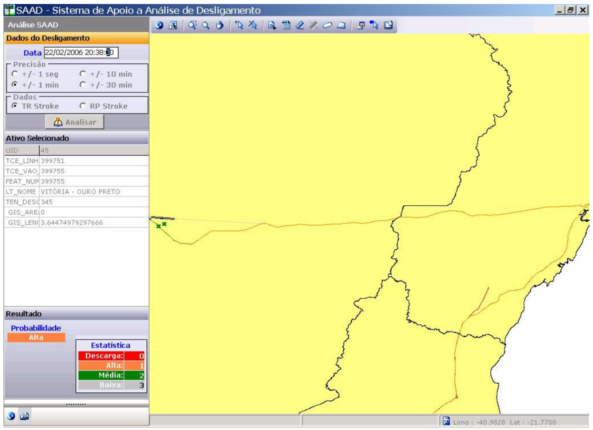

Figure 7: Example of "High Probability Lightning" Result

3 APPLICATION

In order to show, in operational terms, how SAAD can be applied for a power utility, improving the quality of the outages information, concerning their causes, some of FURNAS transmission lines were chosen.

The criteria used to choose them was their rate of outages per kilometer and per year, which consists in the total amount of outages, divided by its extension and by the period of time considered, as shown on the next equation (1).

$$Outage\ Rate = \frac{Number\ of\ Outages}{Extension(km) \times years} \quad (1)$$

This rate is used internationally to evaluate transmission lines performances and to make possible the comparison among different ones on a same base.

Another important aspect that was considered to choose the transmission lines was the previous classification of those outages, given by the operational stuff without taking into account any lightning location system analysis. So the rates were calculated considering the outages previously classified as caused by "lightning" and as "undefined cause", which could in fact be related to lightning phenomenon.

In this way, the following transmission lines were selected.

3.1. Vitória - Ouro Preto

Connecting the main city of Espírito Santo State to the National Power System grid, this transmission line is located in some of the highest lightning density region in Brazil. This transmission line was energized on March 25th 2005, operates in 345 kV and its extension is 383 kilometers. On the next figure, taken from GISFURNAS, the representation of the transmission line can be seen.

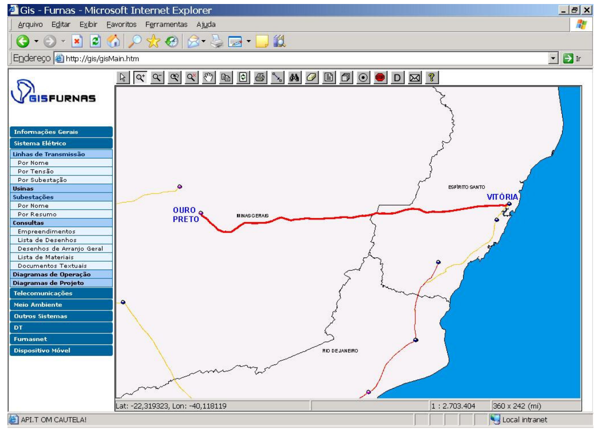

Figure 8: Vitória - Ouro Preto

The period of time considered in the evaluation for this transmission line was since its operation beginning until the end of 2006.

3.2. Gurupi - Miracema

This transmission line is one of the responsible for the connection between the North and South/Southeast National power grids. It was energized on March 2nd 1999, operates in 500 kV and its extension is 255 kilometers. On the next figure, taken from GISFURNAS, the representation of the transmission line can be seen.

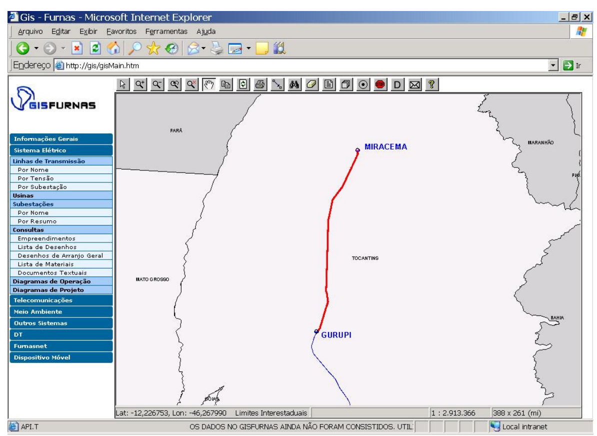

Figure 9: Gurupi - Miracema

The period of time considered in the evaluation for this transmission line was 5 years, from the beginning of 2002 until the end of 2006.

3.3. Corumbá - Brasília Sul

This transmission line is one of the responsible for supplying the Federal District of Brazil. It was energized on March 2nd 1997, operates in 345 kV and its extension is 254 kilometers. On the next figure, taken from GISFURNAS, the representation of the transmission line can be seen.

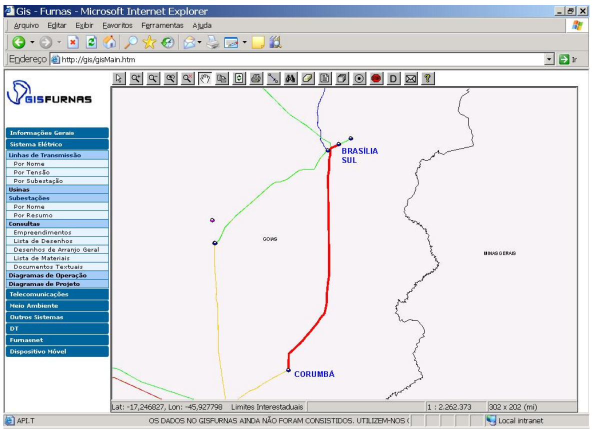

Figure 10: Corumbá - Brasília Sul

The period of time considered in the evaluation for this transmission line was 5 years, from the beginning of 2002 until the end of 2006.

3.4. Cachoeira Paulista - Campinas

This transmission line is one that supplies Campinas, a important city in São Paulo State. It was energized on September 21st 1977, operates in 500 kV and its extension is 223 kilometers. On the next figure, taken from GISFURNAS, the representation of the transmission line can be seen.

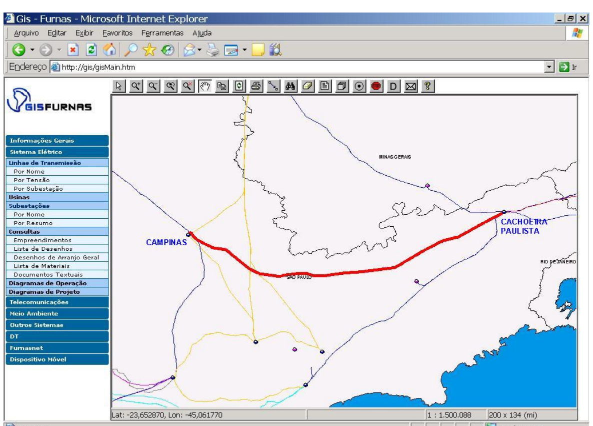

Figure 11: Cachoeira Paulista - Campinas

The period of time considered in the evaluation for this transmission line was 5 years, from the beginning of 2002 until the end of 2006.

4 EVALUATION

The main purpose of the evaluation is comparing two kinds of outage data for each transmission line, concerning their causes.

The first group of data will be the one given by the operational stuff, without any lightning location system analysis. This group represents the outages that were classified as caused by "lightning" or as "undefined cause", occurred at the transmission lines selected, during that period chosen and it will be called "Before SAAD" Data.

The other group will be the same outages data base presented before, but with the new cause classification after analyzed at SAAD, that can be: No Lightning, Lightning Low Probability, Lightning Medium Probability or Lightning High Probability. This group will be called "After SAAD" Analysis.

After both data presentation, a comparison will be held to show the differences between the data and how difficult it is to determine transitory outages causes without a customized lightning location system analysis, as SAAD.

4.1. Vitória - Ouro Preto

Table 1: Vitória - Ouro Preto Results

Year	Before SAAD		After SAAD (Lightning Probability)							
			High	%	Medium	%	Low	%	NO	%
2005	"Lightning"	7	3	43	0	0	2	29	2	29
	"Undefined"	0	-	-	-	-	-	-	-	-
2006	"Lightning"	8	4	50	0	0	2	25	2	25
	"Undefined"	1	0	0	0	0	0	0	1	100
Total	"Lightning"	15	7	46	0	0	4	27	4	27
	"Undefined"	1	0	0	0	0	0	0	1	100

As it can be seen from Table 1, the only outage classified as "undefined" was not related to lightning and from the 15 outages classified as having been caused by lightning, 46% had a high probability to be correctly classified, 27% had a low probability and 27% was not related to lightning.

4.2. Gurupi - Miracema

Table 2: Gurupi - Miracema Results

Year	Before SAAD		After SAAD (Lightning Probability)							
			High	%	Medium	%	Low	%	NO	%
2002	"Lightning"	4	0	0	0	0	0	0	4	100
	"Undefined"	13	0	0	0	0	0	0	13	100
2003	"Lightning"	3	0	0	0	0	0	0	3	100
	"Undefined"	7	0	0	0	0	0	0	7	100
2004	"Lightning"	6	0	0	0	0	0	0	6	100
	"Undefined"	22	0	0	0	0	0	0	22	100
2005	"Lightning"	7	1	14	0	0	0	0	6	86
	"Undefined"	14	0	0	0	0	0	0	14	100
2006	"Lightning"	3	0	0	0	0	1	33	2	67
	"Undefined"	32	0	0	1	3	0	0	31	97
Total	"Lightning"	23	1	4	0	0	1	4	21	91
	"Undefined"	88	0	0	1	1	0	0	87	99

From Table 2, it can be observed that in the group of 23 outages classified as having been caused by lightning, just 1 had a high probability to be correctly classified and another had a low probability. The others 21 outages, which represent 91% were not related to lightning at all. And from the group of 88 outages with undefined causes, just 1 had a medium probability to have been caused by lightning.

4.3. Corumbá - Brasília Sul

Table 3: Corumbá - Brasília Sul Results

Year	Before SAAD		After SAAD (Lightning Probability)							
			High	%	Medium	%	Low	%	NO	%
2002	"Lightning"	5	0	0	0	0	0	0	5	100
	"Undefined"	9	0	0	0	0	0	0	9	100
2003	"Lightning"	4	1	25	0	0	0	0	3	75
	"Undefined"	7	1	14	0	0	0	0	6	86
2004	"Lightning"	8	1	13	0	0	0	0	7	88
	"Undefined"	23	2	9	1	4	0	0	20	87
2005	"Lightning"	0	-	-	-	-	-	-	-	-
	"Undefined"	11	1	9	0	0	0	0	10	91
2006	"Lightning"	5	1	20	0	0	0	0	4	80
	"Undefined"	21	0	0	0	0	0	0	21	100
Total	"Lightning"	22	3	14	0	0	0	0	19	86
	"Undefined"	71	4	6	1	1	0	0	66	93

From Table 3, it can be seen that in the group of 22 outages classified as having been caused by lightning, 3 had a high probability to be correctly classified, while the others 19, about 86%, were not related to lightning. From the group of 71 outages with undefined causes, 4 (6%) had a high probability to have been caused by lightning and another one had a medium probability.

4.4. Cachoeira Paulista - Campinas

Table 4: Cachoeira Paulista - Campinas Results

Year	Before SAAD		After SAAD (Lightning Probability)							
			High	%	Medium	%	Low	%	NO	%
2002	"Lightning"	1	1	100	0	0	0	0	0	0
	"Undefined"	1	0	0	1	100	0	0	0	0
2003	"Lightning"	0	-	-	-	-	-	-	-	-
	"Undefined"	2	1	50	0	0	0	0	1	50
2004	"Lightning"	0	-	-	-	-	-	-	-	-
	"Undefined"	0	-	-	-	-	-	-	-	-
2005	"Lightning"	1	1	100	0	0	0	0	0	0
	"Undefined"	2	0	0	0	0	0	0	2	100
2006	"Lightning"	4	2	50	0	0	0	0	2	50
	"Undefined"	0	-	-	-	-	-	-	-	-
Total	"Lightning"	6	4	67	0	0	0	0	2	33
	"Undefined"	5	1	20	1	20	0	0	3	60

From Table 4, it can be observed that from the 6 outages classified as having been caused by lightning, 4 had a high probability to be correctly classified and 2 were not related to lightning. From the group of 5 outages with undefined causes, 1 had a high probability to have been caused by lightning, another had a medium probability, and others 3 were not related to lightning.

5 CONCLUSION

Based on the differences observed between the previous classification of the causes of many outages and the results showed after the SAAD analysis, this paper asserts the importance for power utilities to have systems like SAAD, customized to its own interests. Once the operational and maintenance staff are able to classify the causes of the outages more precisely, the actions of engineering can be more optimized, saving resources and obtaining more effective results, concerning the transmission system performance.

6 REFERENCES

[1] RINDAT available in www.rindat.com.br accessed on July, 2nd 2007.

[2] FURNAS available in www.furnas.com.br accessed on July, 2nd 2007.

[3] J. G. Anderson, F. A. Fisher and E. F. Magnusson, "EHV Transmission Line Reference Book", Chapter 8: Calculation of Lightning Performance of EHV Lines published in 1968 by Edison Electric Institute.