INVESTIGATION OF THE EFFECTS OF THE PRESENCE OF LARGE BIRDS ON OVERHEAD LINE STRUCTURES IN BRAZIL

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Abstract: This paper describes the main actions that have been taken into account by the Brazilian utilities to solve problems regarding birds on overhead line structures and some results obtained from laboratory tests to evaluate the effect of bird dropping deposition on the insulator surface. The Buff-necked Ibis (*Theristicus caudatus*), also known as Curicaca in Brazil, is the responsible for this problem. The tests were performed with the aim of determining if bird droppings can reduce the electrical strength of contaminated insulators. Samples removed from the field and insulators artificially contaminated were submitted to test in the fog chamber to evaluate their electrical behaviour. Some analyses related to the corrosive effect of bird droppings on metallic parts of towers and insulators were also done. The evaluation showed bird streamers as the main cause of flashovers occurred in some transmission and distribution lines.

1 INTRODUCTION

Many utilities all over the world have experienced outages in their electrical systems whose causes are unknown. After some investigations they are attributed many times to bird streamers [1-4]. Besides, in other cases bird droppings on insulator surface can lead to a voltage breakdown in the presence of humidity. Some bird attacks in composite insulators are also experienced in many countries. Environmental rules establish restrictions regarding some actions against birds that use transmission and distribution line structures for roosting and/or nesting. So, considering the environmental preservation and at the same time keeping the electrical system reliability the utilities are lead to employ different procedures of acquaintance with birds. Normally the problem on the transmission and distribution portions of a power system is due to large birds.

After investigating and determining that these birds are responsible for the line outages, many activities performed by the utilities are related to define the appropriate method to solve the problem. Usually the selected method depends on the type and number of structures involved. If only a few poles are causing the problem, perching guards can be used successfully. On structures with numerous places to perch insulator shields can be installed. Some utilities use perching guards and insulator shields to prevent the birds from roosting directly over the insulators, but allow them free use of the rest of the structure.

In Brazil, some utilities have problem with birds on their overhead line structures [5, 6]. There is substantial evidence that bird streamers are a major cause but the other two kinds of problem mentioned above have also occurred in distribution and transmission overhead lines. The Buff-necked Ibis (*Theristicus caudatus*), also known as Curicaca in Brazil (see Figure 1), is the main responsible for the problem.

Figure 1: Curicaca

It is a resident bird and its habitat includes existing open fields in the central area of the country, called “cerrado”, as seen in Figure 2, which leads it to perch, roost and nest on overhead line structures that cross them.

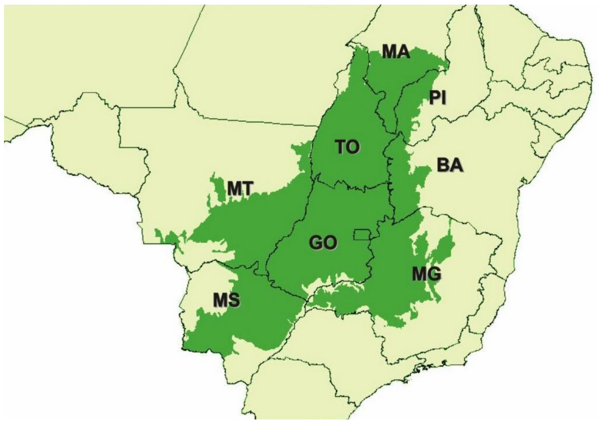

Figure 2: The Brazilian Cerrado

This paper describes the main actions that have been taken into account by the Brazilian utilities to solve problems regarding birds on overhead line structures and some results obtained from laboratory tests to evaluate the effect of bird dropping deposition on insulator surface.

The laboratory tests were performed with the aim of determining if bird droppings can reduce the electrical strength of contaminated insulators. Samples removed from the field and insulators artificially contaminated were submitted to electrical test in fog chamber to evaluate their withstand characteristic.

Some analyses related to the corrosive effect of bird droppings on metallic parts of towers and insulators were also done.

2 FIELD EXPERIENCE IN BRAZIL

CEMIG, the utility which acts in the State of Minas Gerais (MG in the map showed in Figure 2), had many unidentified outages in some distribution and transmission lines. From 2003 it experienced an increase of this kind of faults reaching 70% of all registered outages and leading it to investigate the causes deeply [5].

Two different distribution lines had special attention due to the excessive number of transient faults.

The first one was TL Brasilândia 2 – Buritis, 69 kV, 195.4 km long. During the period from Jan/03 to Dec/04, 65% of 76 transient faults were classified as outages with unidentified causes. Although this line has concrete, wood and metallic poles all faults were located at the last type. One has observed that:

- 96% of outages have occurred between 6:00 pm and 6:00 am;
- 84% of faults have occurred on the upper phase and on the separated phase;
- 100% of faults have been phase-to-ground short-circuits with posterior satisfactory reclosures.

The second one was TL Iguatama 2 – Luz 1, 69 kV, 55 km long constructed with metallic towers. In the same period, 84% of 56 transient faults had unidentified causes and the same characteristics showed above were observed.

After inspections CEMIG's technicians have noted flashover marks on conductors, fittings and crossarms in many towers. Talking with people that live in that region they have known about birds which roost on the towers during the night and have concluded that the problem was related to the presence of Curicacas in the towers, as seen in Figure 3 and after comparing these results with data obtained in the literature they have confirmed the causes were bird streamers.

Figure 3: Curicacas perched on metallic tower of 69 kV TL [5]

Many other transmission and distribution lines that cross the region in northwest part of the state including an important 500 kV line have been inspected and some actions have been taken into account.

Due to the presence of bird droppings on some insulators, as seen in Figure 4 and 5, technicians have decided to substitute all the affected insulators by clean ones in aim to prevent outages related to pollution.

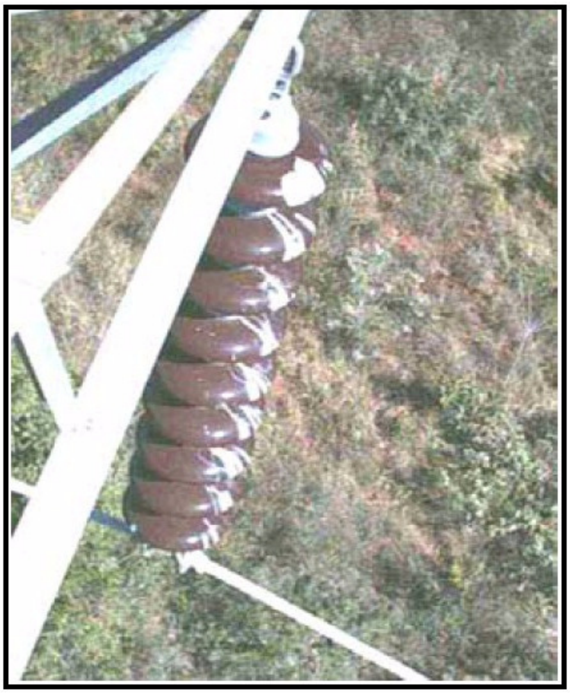

Figure 4: Curicaca's droppings on 138 kV TL insulator surface [5]

Figure 5: Curicaca's droppings on 69 kV TL insulator surface [5]

In all towers on which Curicacas have been observed, technicians have put perching guards in the position over insulator string, as showed in Figures 6 and 7.

Figure 6: Perching guard cone type [5]

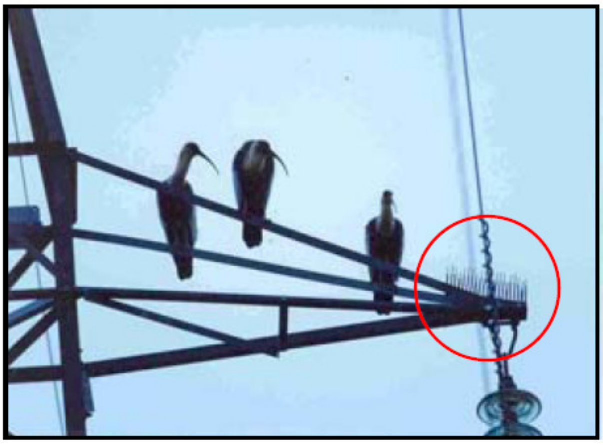

Figure 7: Perching guard needle type [5]

Inspections on those DLs and TLs have increased and the outages have decreased drastically due to all actions.

Other utility, Plena Transmissoras, that has TLs which cross the states of Mato Grosso (MT), Goiás (GO) and Tocantins (TO) has also experimented several outages in two 500 kV TLs six months after energised in 2003 [6].

In a similar way technicians have looked for the causes and the investigations have lead them to identify the same issues: transitory outages during night and early morning, phase-to-ground flashovers and flashover marks at crossarms, conductors and fittings. In this case, all flashovers have occurred in the middle phase and along of entire lines.

During inspections they have confirmed the presence of Curicacas, as one can see in Figure 8, and have concluded that bird streamers were the cause of the outages.

Figure 8: Curicaca roosting on the 500 kV tower [6]

The solution adopted by technicians was to install perching guards in all 1287 towers of both TLs, after cleaning the crossarms.

No outages related to bird streamers were observed since such a solution was implemented. However, some tests had been performed at laboratory with aim to avoid the need of posterior insulator cleaning and to verify how corrosive these bird droppings were.

3 LABORATORY TESTS

The central insulator string configuration in these 500 kV TLs is "V" which means that all insulators can be subjected to Curicaca's droppings on their top surface. To evaluate its electrical behaviour under such condition, one "V" insulator string with 24 units each leg have been removed from the line and 30 insulators have been sent to CEPEL's laboratory for the following tests [7]:

- Determination of ESDD related to Curicaca's droppings;
- Evaluation of physical-chemical characteristics of the material deposited on insulator surface and evaluation of its corrosion degree;

- Determination of the withstand voltage of a similar insulator string artificially contaminated with the same ESDD value;

- Verification of the electrical withstand of the insulator string naturally contaminated under withstand voltage.

In Figure 9 one can see some insulators removed from service just after received at laboratory.

Figure 9: Insulators removed from service [7]

3.1 ESDD Measurement

Four insulators were used to ESDD measurements according to the procedures established in IEC60815 [8]. The results of ESDD measurement on top insulator surface are showed in Table 1.

Table 1: ESDD measurement

Sample	ESDD (mg/cm^2)
Insulator #1	0,033
Insulator #2	0,240
Insulator #3	0,169
Insulator #4	0,122

3.2 Physical-chemical characteristics

The same material removed from the insulator surface using for ESDD measurement was used to perform physical-chemical analyses whose results are shown in Table 2.

Table 2: Results of physical-chemical analyses

Sample	Volume of solution (ml)	pH	$\sigma_{20ºC}$ (S/m)	Residue after evaporation (g/l)	Non volatile material at 600 ºC (%)
Insulator #1	191	7.5	8.5×10^{-2}	0.4	31.8
Insulator #2	171	8.5	8.8×10^{-1}	11.9	32.1
Insulator #3	191	7.9	5.1×10^{-1}	1.7	43.1
Insulator #4	193	7.5	5.4×10^{-1}	3.9	31.8

As one can see in Table 2, approximately two thirds of the residue was constituted by organic material that became volatile. The remaining material was qualitatively evaluated using energy dispersion in a scanning electron microscope (SEM) and the results are shown in Table 3.

Table 3: Metallic and semi-metallic elements present in the non volatile material of each sample

Element	(%) per sample			
	Insul. #1	Insul. #2	Insul. #3	Insul. #4
Al	10.64	13.04	8.41	14.73
Si	20.08	10.99	9.01	16.69
P	6.11	8.04	6.85	5.87
S	2.59	2.81	1.27	1.63
Cl	-	0.41	3.47	0.84
K	10.65	7.46	20.56	11.52
Ca	14.72	21.99	8.82	11.63
Ti	1.68	1.64	1.94	2.08
Fe	24.88	31.21	32.63	31.46
Zn	8.66	2.41	7.02	3.56
Total	100.00	100.00	100.00	100.00

Values in red indicate the two elements whose amount is greater in each sample representing approximately 50% of the total.

The results show the significant presence of iron that can be explained in part by Curicaca's way of catching food in the soil that can also justify the presence of Si, Ca and K.

On the other hand, the low amount of zinc possibly can indicate that there is a small but not significant corrosion process taking place on the metallic parts of insulators and structures.

Corrosion in an aqueous environment and in an atmospheric environment (which also involves thin aqueous layers) is an electrochemical process because corrosion involves the transfer of electrons between a metal surface and an aqueous electrolyte solution. It results from the overwhelming tendency of metals to react electrochemically with oxygen, water, and other substances in the aqueous environment.

Due to the fact that bird droppings are aqueous it is possible to be adequate medium to corrosion process. On the other hand, the environment conditions existing in the Brazilian Cerrado are low relative humidity and high sun radiation effect that keep dry the material deposited on the insulator surface, besides that region is typically rural.

However, to evaluate the corrosion process deeply it is necessary to take into account characteristics as pH and electric conductivity measured from the water solution resulting of insulator cleaning.

Figure 10 presents a simplified Zn Pourbaix diagram. This kind of diagram indicates the electric potential which characterizes the possible chemical reactions in function of pH value of the water solution. The region classified as passivity represents the one where corrosion process is negligible. In the Zn case it is between 7 and 14.

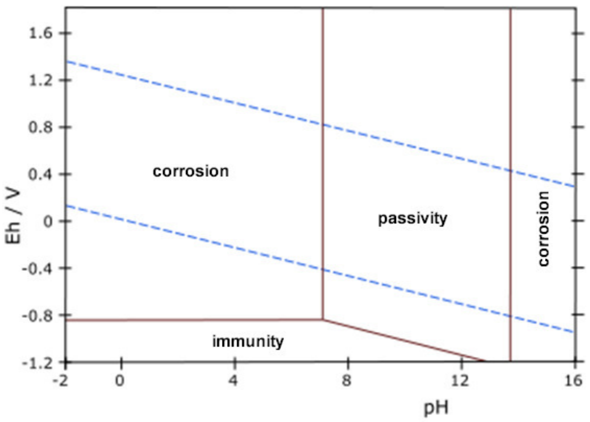

Figure 10: Zn Pourbaix diagram (adapted from [9])

Although the electric conductive values presented in Table 2 are significant the pH values around 7.5-8.5 indicate that Curicaca's droppings are non corrosive in this case.

3.3 Determination of the withstand voltage of a similar insulator string artificially contaminated

The SDD value adopted to this determination was 0.14 mg/cm^2 obtained as the average value from the four measurements showed in Table 1.

The tests were performed according to IEC 60507 [10] with kaolin as inert material in the solid layer method and clean fog generated by nozzles.

Due to temporary limitation of the power source and considering the linearity observed in withstand voltage tests related to insulator string length [11] the determination was done taking into account three different lengths with 6, 10 and 14 units at the same actual configuration where the other units in the string at the ground side were short-circuited. Only one leg of V string was under test while the other was kept cleaned.

Insulators had its bottom surface roughly cleaned to represent field conditions where the relation top ESDD/bottom ESDD is high. Table 4 presents the test results.

The determination of maximum withstand voltage to the entire leg of insulator string with 24 contaminated units was done by extrapolation, assuming the linearity mentioned above. Figure 11 indicates the value of 545 kV as this result. This value is 80% greater than the maximum phase-to-ground voltage of the line.

Table 4: Test results

Insulator string lenght	Maximum withstand voltage (kV)
6 units	120
10 units	220
14 units	330

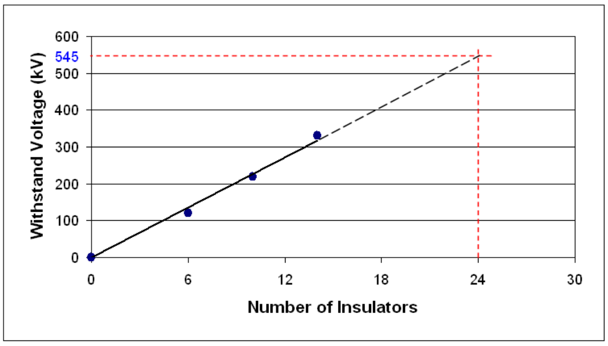

Figure 11: Determination of maximum withstand voltage of 24 contaminated insulator string (one leg of the V configuration)

3.4 Verification of the electric behaviour of insulator string naturally contaminated under the maximum withstand voltage

With the aim of verifying the electric behaviour of the naturally contaminated insulator string, one leg with 24 units removed from the field of the V configuration was submitted to the maximum withstand voltage calculated before under clean fog condition in the laboratory. Figure 12 shows the test arrangement. The left string is the naturally contaminated while de right one is kept cleaned. An additional insulator is included at the ground side to allow the measurement of the leakage current. The voltage was applied during 1 hour and no electrical activity was observed on the insulator string, confirming that the flashovers occurred in the field were due to bird streamers.

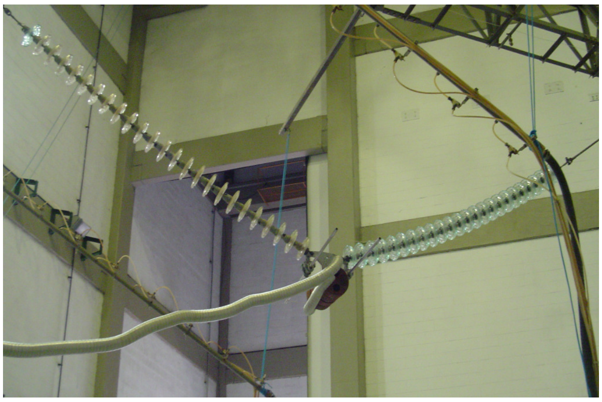

Figure 12: Test arrangement with the V configuration insulator string [7]

4 CONCLUSIONS

Many outages experienced by some utilities in Brazil are due to bird streamers specially in the central area where Curicacas live. The application of some kind of guard perching has been successfully used.

Tests performed at Cepel's laboratories indicated that:

- the average value of ESDD measured on insulators removed from service was 0.14 mg/cm^2;
- the physical-chemical characteristics of Curicaca's droppings removed from in-service insulator surface, associated with the environmental conditions existing in the central area of Brazil, produced negligible corrosive effect on the metallic parts of insulators and structures;
- Curicaca's droppings on top insulator surface in the V string configuration did not lead to a flashover under operational voltages.

New researches shall be done with the aim of testing HVDC insulator strings due to implantation of HVDC TLs that will cross the Brazilian Cerrado.

5 ACKNOWLEDGMENTS

The author would like to thank the technicians Jorge Ribeiro, Jorge Oliveira and Carlos Fontes for the HV tests, Luiz Alberto Silva for the physical-chemical analyses and Eng. Mauro Zanini for the corrosion analysis.

6 REFERENCES

[1] J. T. Burnham, "Bird Streamer Flashovers on FPL Transmission Lines", IEEE Transactions on Power Delivery, Vol. 10, No. 2, April 1995

[2] C. Van Rooyen, H. Vosllo and R. Harness, "Whacth the Birdie!", IEEE Industry Magazine, Vol. 9, issue 5, p 55-66, Spt-Oct 2003, USA

[3] R. E. Macey and W. L. Vosloo, "Outages of the Brand-se-Baai 132kV feeder - The pollution problem that wasn't," 4th Cigré Southern Africa Regional Conference, CapeTown, South Africa, 2001

[4 F. Kaidanov, R. Munteanu, "High rate of failures on one HV overhead transmission line caused by birds", 19th Convention of Electrical and Electronics Engineers in Israel, Nov 1996, Israel

[5] A. D. Andrade, D. B. Resende, E. R. Soares, J. C. M. Lima, M. G. Oliveira, O. L. Santos, P. S. L. Araújo, R. L. Markiewicz, T. G. A. Faria, "Influence of Bird Behaviour on OHTL Operation", Paper GLT 26, XVIII SNPTEE, Curitiba, Brazil, 2005 (in Portuguese)

[6] C. P. Silva, M. O. Silva, M. M. Nogueira, O. P. Santos, S. P. Carvalho, "Outages in 500 kV TLs Caused by Curicacas: Identification, Tests and Solution", XII ERIAC, Foz do Iguaçu, Brazil, 2007 (in Portuguese)

[7] R. W. S. Garcia, T. B. Rodrigues, V. H. G. Andrade, "Bird Droppings: Their Effects on the Electrical Behaviour of OHTLs", Technical Report CEPEL no. DIE 44960/06, Rio de Janeiro, Brazil, 2006 (in Portuguese)

[8] IEC 60815-1, "Selection and dimensioning of high-voltage insulators for polluted conditions - Part 1: Definitions, information and general principles", 2009

[9] http://commons.wikimedia.org/wiki/File:Zn-pourbaix-diagram.svg, last accessed: May 05, 2011

[10] IEC 60507, "Artificial pollution tests on high-voltage insulators to be use on a.c. systems", 1991

[11] NGK Technical Guide, Cat. No. 91 R, Japan, 1989