21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

D1 - 111

CIGRE 2016

The Effect of Bird Streamers on the Insulation Strength of HVDC Lines

N. Mahatho [1,2], N. Parus [1,2], T. Govender [1,2], W.S. Miya[1], H. F. Vosloo[1] and G. Sibilant [3]
1. Eskom Holdings SOC Ltd, South Africa
2. University of Witwatersrand, South Africa
3. Electric Power Research Institute, United States of America

SUMMARY

Bird streamers are a known cause of transmission line faults. Much work has been done to understand this phenomenon for HVAC transmission lines, however, there is considerably less work done for the HVDC case. In South Africa, bird streamer faults contribute to 38% of HVAC line faults, but for the Cahora Bassa HVDC line this number has yet to be verified. It is also not known if such a phenomenon could possibly occur on an HVDC line. The Cahora Bassa hydro-electric scheme is a crucial asset in the power utility's generation pool and the 1500 km long transmission lines are required to have a very high reliability and availability. The bird streamer fault mechanism under HVDC polarity needs to be properly understood in order to mitigate against this problem and for the design of new lines. Testing was thus conducted to determine the effects of bird streamers on the flashover performance of HVDC transmission lines. For the purpose of this paper, only positive polarity results are reported and discussed. It has been shown by comprehensive laboratory tests that it is possible to recreate bird streamer faults for the Cahora Bassa transmission line. It was shown that bird streamers from approximately 2.8 m in length could cause line faults. The size and volume of the streamer is an important factor in determining the probability of a flashover.

KEYWORDS

HVDC, Bird Streamer, Line Faults

nishal.mahatho@eskom.co.za

INTRODUCTION AND BACKGROUND

High Voltage Direct Current (HVDC) schemes generally transmit large amounts of power over long distances. Due to power flow balance, such schemes also generally have high availability requirements and any outage or transient fault on an HVDC line could cause the loss of power to many customers or quality of supply problems.

Transmission line faults, with no apparent cause, have puzzled engineers for decades. As far back as 1920, Burnham [1] cited Michener [2] who proposed the idea of line faults resulting from long streams of a watery mixture of urine and faeces emitted by large birds – known as bird streamers. Initially it was speculated that high voltage stress at sharp points on the line hardware was responsible for the unexplained faults. This situation was corrected by covering these sharp points with copper balls, but the faults then increased instead of decreasing. A revelation occurred when a line worker witnessed an eagle releasing a long stream of excrement and this then led to problem bird species such as eagles, hawks and herons being identified as the culprits of these unexplained faults. The copper balls actually reduced the air gap size and provided a larger size target for the bird streamer to terminate on. Burnham, concluded that this mechanism was not recognized because it occurs mainly at night, in remote areas, and leaves very little evidence. As these birds also roost on the towers at night and fly around in search of food, field patrols rarely observe the birds responsible for these faults [3].

In South Africa, vultures are drawn to areas where the Cahora Bassa HVDC transmission line passes close to spots known as “vulture restaurants” or on farms where both wild and domestic animals present a food source. Artificial feeding areas are created where livestock farmers dispose of carcasses of dead animals, which the vultures feed on. After eating their fill during the day, these birds then perch on the line’s pylons. During the night or early morning it releases a streamer, which if directed into an electrically vulnerable area, may lead to a flashover of the line. Vultures are not the only type of bird that is known to utilise the pylons, and many other large birds have also been observed perching on them (see Figure 1). Figure 2, shows birds in the act of streaming on the top of the pylon. The streamers captured in Figure 2, did not cause a fault event. Due to the angle of the camera installation it was not possible to determine the lengths of the streamers shown in Figure 2.

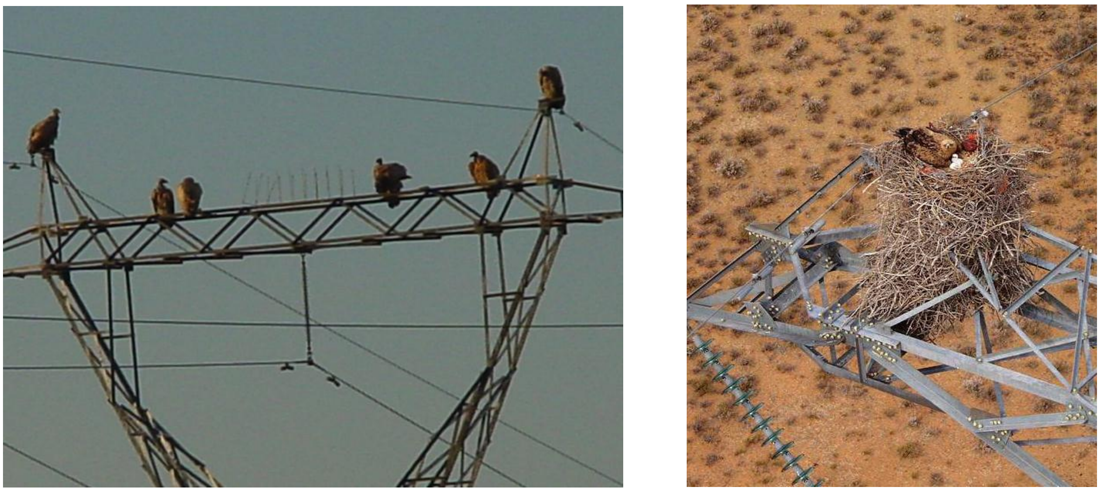

Figure 1: Examples of birds roosting and nesting on transmission towers

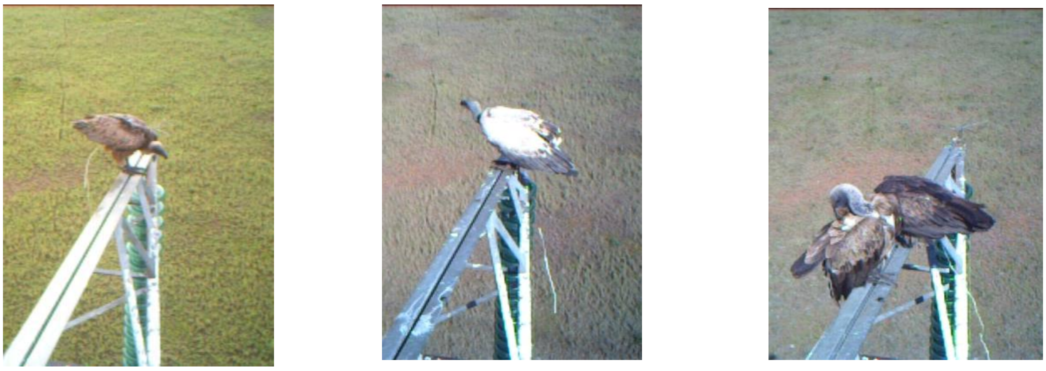

Figure 2: Large birds releasing streamers on top of a HVDC transmission line

The percentage of faults caused by bird streamers on the South African sections of the Cahora Bassa HVDC line is not accurately known and is currently being investigated. Approximately 38% of all faults on the South African HVAC network are attributed to this phenomenon [3, 9]. No correlation can this far be made relating to the difference between positive and negative polarity line faults as the Cahora Bassa line has a unique configuration in that the different poles are separated into two lines that are spaced approximately 1 km apart.

DESCRIPTION OF THE TEST SETUP

A test programme was developed in order to try to better understand the fault mechanism and hence to propose mitigation measures so that the problem may be adequately managed. Tests were done at both the National Electrical Testing Facility's (NETFA) high voltage laboratory in Midrand, South Africa, and at the Electric Power Research Institute's (EPRI) high voltage laboratory in Lenox, USA. The Cahora Bassa HVDC line pylon structure was replicated in both the laboratories (see Figure 3). A bird streamer replicator device was developed to simulate the condition. The tests were done at a representative +533 kV voltage. A HVDC glass cap and pin insulator string consisting of 28 insulators was used. The connecting length was 4.5 m. The test programme involved simulating bird streamers occurring at various positions in the space between the pylon, the insulator and the live transmission line. The EPRI tests were done under controlled temperatures which are applicable to local conditions in South Africa. The tests were therefore done indoors. This allowed the room test temperature to be controlled by heating the test building.

Figure 3: A replica of the Cahora Bassa pylon dimensions in the EPRI HV laboratory

Bird streamer flashovers have been simulated by numerous investigators [4-7], and use was made of a variety of excreta substitute, including egg yolk and a soap solution. For the purpose of these tests, the bird streamer itself was simulated by developing an egg-based mixture of similar conductivity and viscosity as liquefied bird excreta. No actual birds were used for these tests. Excreta from birds of prey that were held in captivity were measured to have a conductivity of between 5 and 12 mS/cm. The streamer solution used for these tests had a conductivity of between 5.9 to 6.1 mS/cm. The streamer mixture composition was verified by testing using AC voltage for cases where streamer related faults have already been proven [4-7]. When testing with AC voltage, the mixture resulted in flashovers and was thus proven to be acceptable for these tests.

A Bird Streamer Simulation Device (BSSD) was developed and consisted of a pressure vessel, which was pressurized by a small portable air compressor. The pressurization of the vessel and the streamer release mechanism was remotely controlled for safety purposes. A 24V rechargeable car battery powers all the components. The BSSD is shown in Figure 4.

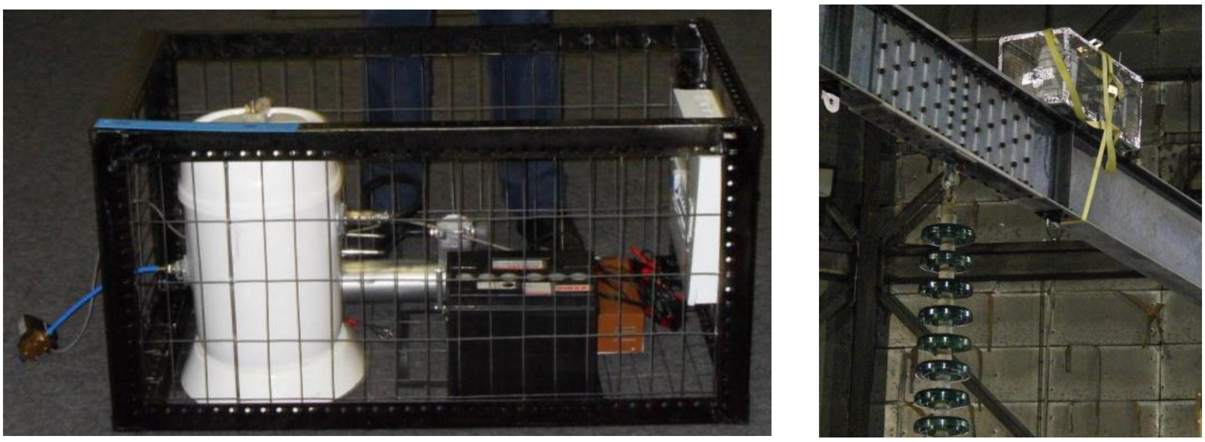

Figure 4: The bird streamer simulation device and its mounting on top of the simulated pylon

The tests involved investigating what effect different lengths of bird streamers parallel to the insulator string would have on flashover. The BSSD was thus designed to create different lengths of streamers and was calibrated, on site, against a graduated/marked background. It was found that a minimum streamer of 1.27 cm (0.5 inch) diameter and of approximately 200 ml volume was required to initiate a flashover.

The tests involved energising the bundle at the representative +533 kV and then releasing streamers at distances of 5, 30, 45, 60, 75 and 90 cm away from the insulator string. Several streamers were released at each position. A high-speed digital video camera was also used in order to capture the initiation and progression of the flashover events.

DISCUSSION OF THE RESULTS

All positions tested up to 90 cm away resulted in flashovers. Several streamers were released at each distance and all of the released streamers resulted in flashovers. The length of the streamer required to cause a flashover varied with distance away from the insulator. As the distance away from the insulator increased, so did the length of the streamer required to cause a flashover. Figure 5 shows the resultant flashover for the 45 cm distance test.

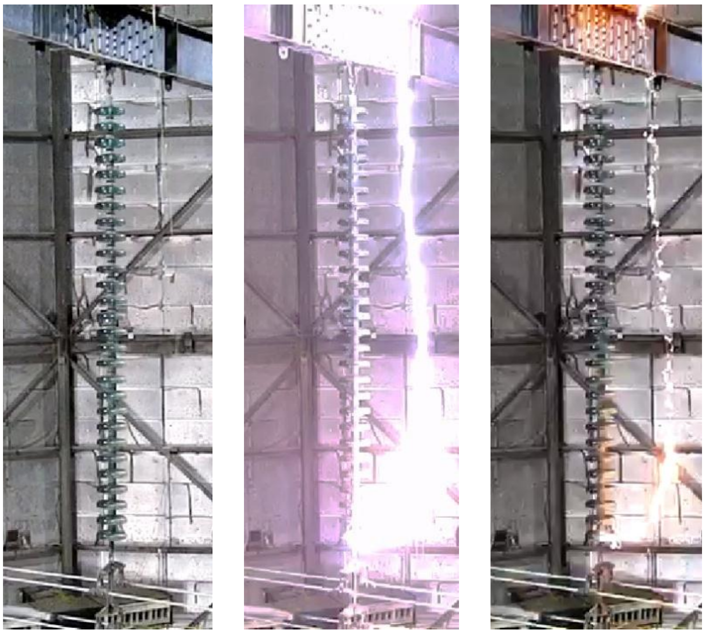

Figure 5: Flashover progression for the streamer 45 cm away from the string (EPRI Lab)

Figure 6, shows a flashover event during the South African tests, at the SABS NETFA HV laboratory. A gravity feed technique was used in this test as part of the investigation into the volume and size of the streamer required for a flashover.

Figure 6: Flashover observed at 30 cm away from the string (NETFA Lab)

Table 1, shows the approximate streamer lengths required for a flashover for each of the distances away from the insulator. Two methods were used to determine the streamer length.

1. Length based on the number of frames from a video camera;

   The length of the streamer was calculated using the time measured from when the streamer was released from the BSSD to when the flashover initiated. The camera was filming at a rate of 30 frames per second (fps). The length of the streamer was calculated using the following formula:

   $L = 0.5 a t^2$……………………………………(Eq. 1)

Where: L = length of streamer in meters.
a = acceleration in $m/s^2 = 9.8\ m/s^2$
t = time in seconds

2. Length based on visual image;

In this method the length of the streamer was estimated based on where the streamer was visible just before flashover occurred. This method might not be as accurate as the first one as it was not always clear where the streamer location was due to the dispersion of the streamer close to the energised end of the insulator string.

Table 1: Approximate streamer lengths required for flashover

Distance from Insulator (cm)	**Frames from release (top of beam) to flashover**	**Length from bottom of beam based on time (m)**	**Visual Number of insulators Bridged**	**Length based on number of insulators (m)**
5	23 (bottom of beam)	2.88	22	3.52
30	26 (bottom of beam)	3.68	22	3.52
45	30	4.30	24	3.84
60	31	4.63	25	4.00
75	32	4.98	28	4.48
90	32	4.98	28	4.48

Based on the results shown in Table 1, the minimum streamer length required for a flashover was approximately 2.8 m (when it was 5 cm away from the insulator string). This result, in part, correlates with the streamer length of 2.5 m that has been found to cause breakdown on 400 kV HVAC lines [11]. These distances were derived from the flash marks on the live conductor and those directly above on the steel members of the tower.

Once the streamer was 75 cm away from the insulator string, a streamer length of approximately 4.4 m was required for a flashover (i.e. the streamer length required for a flashover was approximately the same as the length of the insulator string).

The electrostatic fields around the setup had an effect on the tests. For the initial tests, the fields at the dead end were sufficiently high such that it caused the streamer to break up just as it reached the second or third glass disk position (see Figure 7). Since the streamer was no longer a single liquid stream, no flashover occurred. This result necessitated a closer look into the diameter and volume of the streamer that was required for flashover.

Figure 7: Electrostatic field around the insulator affects the consistency of the streamer

In lieu of mitigation of this problem, a solution known as ‘bird guards’ may be applicable. Bird guards are a finger-like apparatus that is made from UV resistant high-density poly-ethylene. Bird guards have been installed on South African transmission lines as well as in the USA with the purpose of safely keeping birds away from critical/vulnerable areas on the pylon (i.e. in order to prevent streamers to bridge-out the electrical clearance)[10]. These devices was considered successful in preventing streamer faults and during the initial installations, it reduced the number of faults from 450 per annum, in 1999, to 250 at the end of 2001 [3].

Figure 8, shows a bird guard installation of approximately 2m in length. It has been observed that the larger birds are still able to roost on this device, and within the critical position away from the insulator string. Further, as seen in the image on the left (in Figure 8), there is an entire section at the bottom of the cross-arm (which is located in the critical area away from the insulator) that is left unprotected. Birds may be able to access this area. The physical installation and placement of the bird guards will therefore have to be further investigated.

Another option would be to increase the air gap to such a length that it is not practical to expect a streamer long enough to create a flash over. Such a solution has proven to be successful on Eskom’s Matimba-Spitskop 400 kV AC lines [11]. Matimba-Spitskop Line 1 was built with an electrical clearance of 3.2 m and was prone to bird streamer related faults. Matimba-Spitskop Line 2 was built parallel to Line 1 - with an electrical clearance of 4.2 m – and experienced a third of the faults when compared to Line 1. This option, however, is impractical for the Cahora Bassa line as it is not possible to increase the connecting length of the insulator string due to mid-span clearance issues.

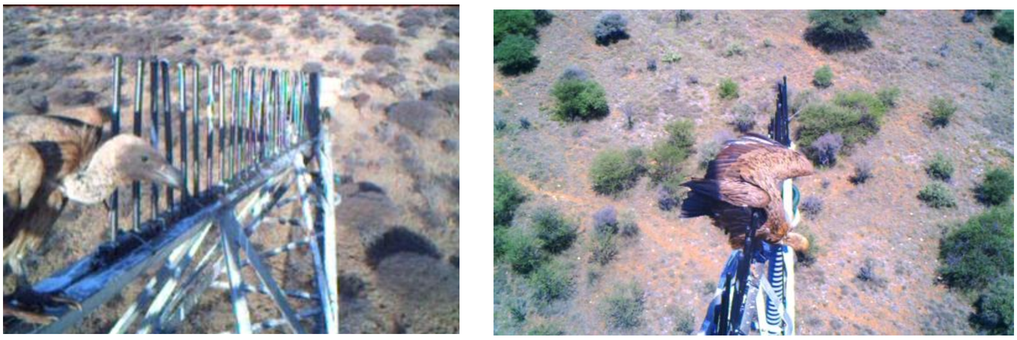

Figure 8: Bird behavior around bird guards

These tests have shown that it is possible to generate a bird streamer type fault on the Cahora Bassa tower configuration. The focus of future work will be to repeat the tests for negative polarity and to identify the types of birds (should they exist) that will be able to produce comparable streamer lengths. Such large volumes of excreta (required to create a flashover) were not observed from birds held in captivity. What is accepted, however, is that line faults due to bird streamer flashovers are occurring on the Cahora Bassa line, so this fact tends to support the hypothesis that large birds (in the wild) may be able to generate the required volume of excreta to cause the flashover. The presence of birds had initially been indicated by way of extensive amounts of excreta observed on the towers of this line [8].

CONCLUSIONS

1. A bird streamer of approximately 1.27 cm (0.5 inch) diameter, with a volume of 200 ml and with conductivity of approximately 5 mS/cm is required in order to practically create a flashover on the specific setup that was tested.
2. For the configuration tested, it is possible to create a bird streamer related flashover up to 90 cm away from the insulator string.
3. The closer the streamer is to the insulator string, the shorter is the length required for a flashover.
4. The minimum streamer length observed for flashover was 2.88 m.
5. Further than 75 cm away from the string, the length of the streamer needs to be almost the same length of the insulator string.
6. The electrostatic field at the dead end also plays a role in the bird streamer flashover process. The field at the dead end is observed to be high enough to dissipate thin streamer.

BIBLIOGRAPHY

[1] Burnham J.T.,“Bird streamer flashovers on FPL transmission lines”, IEEE Transactions on Power Delivery, Vol. 10, No 2, 1995.

[2] Michener H, “Transmission at 220 kV on the southern California Edison system”, AIEE, Vol. XLIII, pages 1223 and 1235, 1924.

[3] Vosloo H.F., “The need for and contents of a life cycle management plan for Eskom transmission line servitudes”, M.Sc dissertation, University of Johannesburg, 2004.

[4] West H. J., Brown J.E. and Kinyon A.L., “Simulation of EHV transmission line flashovers initiated by bird excretion”, Paper 71 - TP 145-PWR, IEEE Winter Power Meeting, New York, N.Y., January 31st - February 5th, 1971.

[5] Burger A.A. and Sadurski K.J., “Experimental investigation of bird initiated AC flashover mechanisms”, Cigre SC 33-95 (WG07), 1995.

[6] Hoch D.A. and Bologna F, “Laboratory study of bird streamer flashover mechanism for different voltages and hardware arrangements”, Internal Eskom research report: Res/RR/0218249, 2003.

[7] Hoch D.A. and Bologna F, “Bird streamer flashover mechanism: Influence of wet contaminated glass and polymer insulators”, Internal Eskom research report: Res/RR/04/23504, 2004.

[8] Govender T, Parus N and Kekana L, “Results from the first download of the bird observation cameras installed on the Cahora Bassa transmission lines – July 2011”, Internal Eskom report D.R8005.18.10, July 2011.

[9] Van Rooyen C, Vosloo H.F. and Harness R, “Eliminating bird streamers as a cause of faulting on transmission lines”, IEEE Rural Electric Power Conference, Colorado Springs 5-7, May 2002.

[10] Vosloo, H.F., “Transmission bird perch guidelines”, Internal Eskom guideline 41-332, 2016.

[11] Vosloo H.F., Britten A. C. and Burger A.A, “The Susceptibility of 400kV transmission lines to bird streamers and bush fires: A definitive case study”, Cigre regional symposium, South Africa 2009.