OUTAGES OF THE BRAND-SE-BAAI 132kV FEEDER – THE INSULATOR PROBLEM THAT WASN'T

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SUMMARY

From its commissioning in June 1994, the 132kV overhead feed to a mine situated at Brand-se-Baai on the West Coast of South Africa displayed unsatisfactory performance. Several line patrols revealed no definite cause of the outages but the pollution flashover of the insulator strings was strongly suspected. Measurement of the contamination levels and local insulator tests did not, however, indicate a high pollution severity. The paper describes the investigation undertaken to establish the precise nature of the faults and to identify the corrective actions necessary to ensure an acceptable quality of supply.

INTRODUCTION

From its commissioning in June 1994, the Eskom 132kV overhead feed to a mine situated at Brand-se-Baai on the West Coast of South Africa displayed unsatisfactory performance with an average phase-to-earth trip rate of 1,3 per month. Several line patrols revealed no definite cause of the outages but, as the west coast region is known for its marine salt pollution, regular fog occurrence and low rainfall, the pollution flashover of the insulator strings was strongly suspected. Local personnel proposed that the entire line be re-insulated with silicone rubber composite long rods.

The installation of directional dust deposit gauges and the establishment of a live insulator test station near the coastal end of the line, however, did not indicate a pollution level of sufficient severity to result in the number of faults experienced. In October 1998, it was thus decided to commission outside consultants specialising in overhead line inspections to undertake a detailed investigation of the line with a view to establishing the exact cause of the trips and to recommend a solution the problem.

This paper serves to describe the techniques used in the investigation, and emphasises the importance of aerial close-visual inspections and detailed analyses of fault statistics in such studies. The results, recommendations, corrective action taken and the subsequent line performance are provided.

LINE DESCRIPTION

The feeder in question comprises two lines in series, namely, the Juno/Koekenaap and Koekenaap/Brandbaai lines. The former is 24km long with 133 suspension structures and 23 strain structures and the latter 50km long with 276 suspension and 53 strain structures.

Both lines are of the 5 wood pole tower design and strung with single Ash conductor. The last 120 towers at the Brand-se-Baai end are insulated with silicone rubber composite long rods with the remainder of the line being equipped with strings of glass discs.

POLLUTION SEVERITY STUDIES

The line trips were initially thought to be caused by the flashover of polluted insulators. This view was supported by the facts that the end of the line approaches the coast where marine pollution is to be expected, the west coast has a low rainfall thus natural washing of the insulators is limited and ilmenite, one of the minerals found in the area, displays high conductivity in solution.

In order to quantify the contamination level, directional dust deposit gauges were installed by Eskom at various points along the line route. The Pollution Indices recorded by these gauges were:

Koekenaap/Brandbaai Line, Structure No.27.................................151
Koekenaap/Brandbaai Line, Structure No.118...............................76
Koekenaap Substation..69
Juno Substation...36

The relationship between the dust gauge Pollution Indices, the IEC Pollution Severity Classifications and the IEC specific creepage distances recommended for insulators in each pollution class are shown below.

Pollution Class	Pollution Index	Specific Creepage
"Light"	0 - 75	16mm/kV Um
"Medium"	76 - 200	20mm/kV Um
"Heavy"	201 - 350	25mm/kV Um
"Very Heavy"	>350	31mm/kV Um

The glass disc strings and silicone rubber composites have specific creepage distances of 28,7mm/kV Um and 31,9mm/kV Um respectively. With the pollution severity ranging from “Light” inland to “Medium” on the coast and the insulators being dimensioned for “Heavy” to “Very Heavy” pollution severity, it is indicated that the line is over-insulated for the ambient conditions and frequent contamination flashover should not be expected.

To gain greater insight into the behaviour of insulation in this environment, an energised insulator testing station was established some 5km from the coast. A directional dust deposit gauge installed at this site registered a Pollution Index of 99. A comparison of the maximum leakage current recorded, (I highest), on the glass and silicone rubber insulators compared to the estimated current amplitude when flashover occurs, (I max), is provided below.

Insulator Type	I highest (mA)	I max (mA)	I highest/I max (%)
Glass disc string	80	3500	2,29
Silicone rubber long rod	5	4300	0,12

It is evident that the insulators under test easily accommodated the contamination levels and other environmental influences present and at no stage were critical flashover conditions approached.

As evidence of the possibility of pollution faults was definitely lacking, there was concern in some quarters that the proposed re-insulation of the line may produce little benefit and that further study was warranted. The project was awarded to external contractors who implemented a comprehensive “rogue” line investigation comprising interviews with key persons, detailed analysis of the fault statistics and an aerial close visual inspection of the feeder.

ANALYSIS OF FAULT STATISTICS

Phase Relationship

A total of 66 unexplained phase-to-earth faults were recorded between July 1994 and October 1998. These were located as follows:

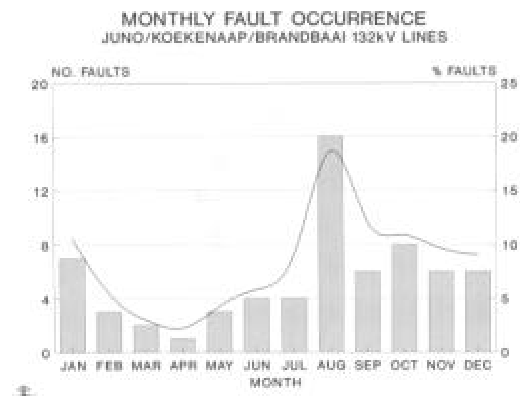
Phase	Number of Faults		Total	Total
	Juno/Koek.	Koek./Brand.	Faults	(%)
Left (Sea side)	0	8	8	12
Centre	13	29	42	64
Right (Inland side)	2	14	16	24

The predominance of faults on the centre phase is significant. If the problem was one of pollution, there is no reason why the centre phase should have a worse performance than the outer phases.

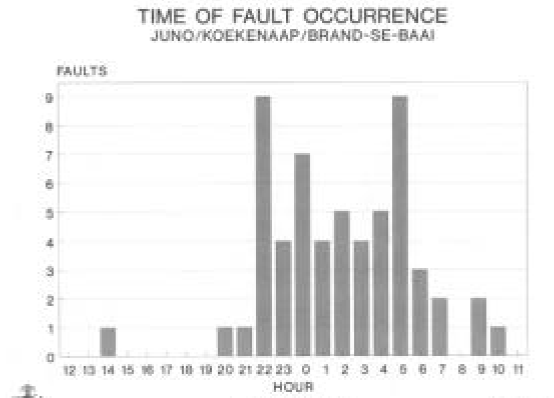
Seasonal Relationship

The occurrence of faults in relation to the time of year is shown in Figure 1. It is evident that the faults peak in spring, remain fairly high during the summer and are far less frequent in winter. For pollution flashovers, one would expect a peak in autumn when the first fogs and drizzle of the winter occur after the long, dry summer.

Although it was claimed by local staff that the trips are "always experienced during periods of mist or light rain" an analysis of the fault records and the prevailing meteorological conditions at the time showed no such correlation.



- FIGURE 1 -

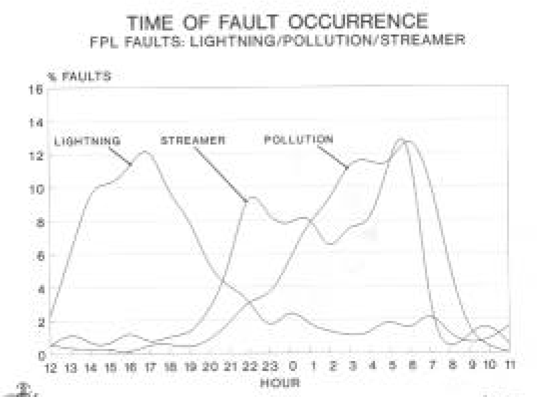


- FIGURE 2 -

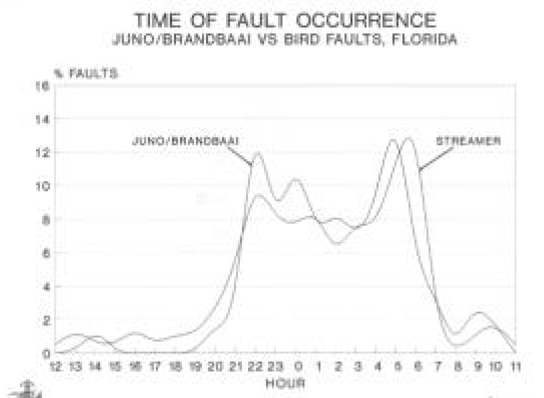
<u>Time-of-Day Relationship</u>

The time of day of the fault occurrences are plotted in Figure 2. It can be noted that approximately 90% of the outages occur at night with definite peaks apparent at 10pm and 5am. Pollution flashovers are expected in the early hours of the morning but are not at all common in the late evening.

From comprehensive analyses of faults undertaken on the Florida Power & Light system [1], time-of-day fault patterns have been established for lightning, insulator pollution and bird streamer outages. These are illustrated in Figure 3. In Figure 4, the bird streamer curve is compared to the trip occurrence curve of the Brand-se-Baai feeder. The Florida data is based on 201 faults on 138kV and 230kV wooden H-pole structures so is well representative of the local situation. The similarity of the two profiles is marked.



- FIGURE 3 -



- FIGURE 4 -

LINE INSPECTION

The main observations made during the aerial close-visual inspection of the lines which related to the possible cause of the faults were as follows:

- The insulators appeared clean and free of any significant pre-deposited contamination. Further, the disc units exhibited no signs of leakage current erosion of the glass or the pins.
- Considerable bird activity in the vicinity of the line was noted. With numerous birds of prey present, streamer type excrement covered many of the crossarms and earthwire peaks. Although there was evidence of streamers on some of the glass discs, no flashover of these had taken place.
- Two composite long rod suspension insulators which had flashed over were found. From their appearance, and the presence of bird excrement on the crossarm above them, it is most likely that the flashover was precipitated by a bird streamer mechanism.
- Other than the two units above, no insulators on the lines had flashed over.
- It was noted that most of the jumpers on the strain structures were too short, resulting in the vertical clearance to the crossarm being less than half the insulator arcing distance. It was further noted that the centre phase jumper, which passes through the tower window, was often shorter than the jumpers on the outer two phases. It is estimated that the BIL was reduced to about 450kV and the power frequency withstand voltage to around 250kV. As there is practically no lightning in this region and the nominal system phase-to-ground voltage is only 76kV, this should not, on its own, cause tripping of the line. On close examination, however, a quantity of 23 jumpers which had flashed to the crossarm were located. It was evident that some of these had faulted more than once.
- On all of the flashed jumpers, the remnants of bird streamers were evident on the jumpers themselves, the crossarm above them and the tower leg below them.

FINDINGS OF THE INVESTIGATION

From the information gathered, it was concluded that the tripping of the line – except for the two flashed composite insulators found – was due to the breakdown of the air gap between the jumpers and crossarms on the strain structures.

The jumpers were too short and, in many cases, the clearance was less than half of the required value. Even so, the gap was adequate to withstand the applied voltages and there was thus some external trigger necessary to precipitate the fault. There is little doubt that this trigger is excrement, in streamer form, ejected by birds roosting on the crossarms above.

Apart from the physical evidence on the line itself, the time-of-day distribution of the faults, with its double peaked, nocturnal characteristic, clearly indicates streamer-related events. The increase in fault occurrence during spring could be attributed to the increased breeding activity at this time.

The reason for the great number of faults on the centre phase is possibly due to the birds favouring the middle of the crossarm for roosting coupled with the fact that the centre phase jumpers were often shorter than those on the other phases.

The flashover of the two composite suspension insulators also appears to be due to a streamer mechanism. These particular units have a shed diameter of only 105mm and a shed spacing of only 27,5mm. Further, although of “alternating” shed design, the difference in shed projection between adjacent sheds of 7,5mm is low. Compared to the longer arcing distance and 146mm shed spacing of the glass strings, the composites are definitely more susceptible to streamer breakdown. The proposed re-insulation of the entire line with composite units might therefore have increased, rather than decreased, the trip frequency.

RECOMMENDED ACTION AND SUBSEQUENT PERFORMANCE

In view of the findings of the investigation, it was recommended that bird guards be placed on the crossarms of, at least, the strain towers, to prevent roosting above the jumpers. Where possible, it was also suggested that the jumpers be lengthened. This was undertaken during 1999. In 2000, no trips were experienced on the Juno/Koekenaap line and only two on the Koekenaap/Brandbaai line. This represents a reduction in average fault occurrence from 1,3/month to 0,17/month. The two faults that did occur are possibly due to the streamer flashover of the composite suspension insulators as has happened previously.

CONCLUSIONS

The examination of the Brand-se-Baai feeder and the circumstances surrounding its poor performance has emphasised the need for thorough investigation of the reason for all trips before making what may appear to be obvious assumptions. Unless the root cause of the outages is firmly established, considerable costs can be incurred in "corrective" measures which may yield no benefit at all or, worse still, aggravate the situation.

One of the lessons learnt from this project is to be careful of pre-conceived ideas and hearsay. For example, statements that the outages always occur when there is rain or fog could not be substantiated by the trip and meteorological data. "The faults always occur at the coastal end of the line" was also a firm belief that the aerial inspection proved false. In fact, the flashed jumpers found were fairly evenly spread over the entire feeder length.

Another lesson is to carefully evaluate the information available. The fact that the majority of faults occurred on the centre phase was not immediately obvious as, contrary to usual practice, on the Koekenaap/Brandbaai section of the line, the blue phase was located in the middle.

Finally, one must ask why the jumpers on this line were shorter than normal. Well, further examination revealed that the cross members of the structures were 12 metres long instead of the 14 metres specified on the drawing. The jumpers were thus pulled tighter to pass through the middle of the now reduced window...

This case serves to illustrate that the unreliability of particular "rogue" lines is usually caused by a chain of events and circumstances which need to be uncovered by careful study before appropriate measures can be defined to restore system security.

REFERENCES

1. J T Burnham, "Bird streamer flashovers on FPL transmission lines", IEEE Transactions on Power Delivery, Volume 10, No.2, April 1995

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