2010
21st International Lightning Detection Conference
19 - 20 April • Orlando, Florida, USA
3rd International Lightning Meteorology Conference
21 - 22 April • Orlando, Florida, USA

LIGHTNING DETECTION IMPROVEMENT FALLS BROUGHT TO ESKOM'S TRANSMISSION LINE DESIGN AND FAULT ANALYSIS

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1 INTRODUCTION

Lightning contributes around 24% to Eskom Transmission's total transmission line faults. Measures have been taken over the past decades to combat this effect of lightning on the performance of high voltage transmission lines and these measures are usually taken after the lines have been constructed and operational for a certain period. From a design perspective, accurate prediction of lightning faults expected for new lines is ideal as this will enable designers to design accordingly.

Eskom's previous lightning detection system was LPATS (Lightning Position and Tracking System) and was decommissioned a couple of years ago to give way to a new lightning detection system, FALLS (Fault Analysis and Lightning Location System)[1].

This paper shares how FALLS has been used in specific investigations to improve fault diagnostics and informing the utility about whether certain faults were due to lightning or not. Looking into the future, perhaps the possibility of being able to download the actual lightning waveform from FALLS for specific strokes of interest which could help with investigations and simulations further.

2 Lightning Activity in South Africa

The figure below highlights lightning activity patterns in the recent years.

(SALDN lightning statistics since Nov 2005)

- Total 65 million strokes
- Average per annum = 24,7 million strokes
- Summer season 06/07 (Oct to Apr)
  - 21,5 million strokes

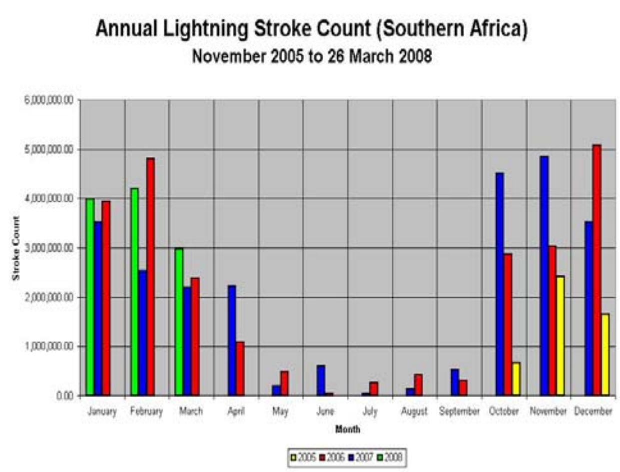

Figure 1: Annual lightning stroke count – SA [2]

The ground flash density map shown below shows the various areas and their ground flash densities. This map is being used in the overhead line design process to perform lightning performance analysis.

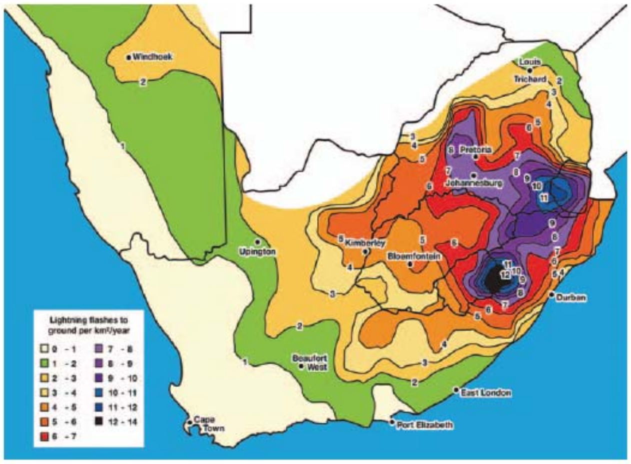

Figure 2: Ground Flash Density map

3 Lightning Detection Networks used by Eskom - History and Current

3.1 LPATS

Eskom was using LPATS and it had served the utility well over the years. Investigations relating to lightning incidents on overhead transmission lines could be done and concluded with the assistance of LPATS, in terms of verifying whether there was a storm in a particular area and what the magnitude of the lightning incident was. LPATS assisted in developing a flash density map to a certain degree.

With advances in technology, questions got asked about its location accuracy and detection efficiency. When applied to lightning incident investigations, there were concerns also about its efficiency relating to successful investigation and diagnosis of lightning incidents on the transmission network. There were times where LPATS would not pickup lightning activity in certain areas where there was lightning activity that was witnessed.

This was more pronounced when a specific area needed to be analyzed, with a buffer zone around it, so that efforts may be concentrated in the study area, LPATS could not perform this task. It also could not assist much at the design stages, where a more accurate ground flash density of the area being traversed by the overhead line was needed. Issues around ability to execute detailed statistical analyses with regards to the stroke magnitudes and frequency in certain areas also were becoming a major challenge.

3.2 FALLS

The most recent acquisition by Eskom with regards to Lightning Location Systems is FALLS and it has already brought about noticeable advantages. Such advantages are its ability to perform regional, small area exposure, gridded exposure and reliability analyses, where through the use of buffer zones, areas of concern can be studied further. Statistical data for the lightning strokes is also made available for further analysis.

The ability to create assets with FALLS has allowed not only investigation of possible lightning impact on existing assets, but as part of new transmission line design, designers are able to investigate various routes and the lightning activity in those routes.

4 Application of FALLS in Overhead Line (OHL) Design

4.1 Route Selection

Prior to the design of an OHL, decisions have to be taken about the route that the OHL will traverse. There are a number of factors that are considered in the process. When a corridor is finally decided on following the environmental impact assessments outcome, 2 or 3 specific routes within that corridor (which can be 2-5 km

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wide) will be chosen. This is where line designers also have a significant input with regards to a better route for the line. A number of issues are looked at, ranging from bend points (which increase the cost of a line if too many), Industrial activities (pollution levels) as well as lightning activity in the area.

Since FALLS was introduced, it is used to zoom into the various routes that are tabled as possible choices and from the various analyses (Regional, Small Area Exposure and Reliabity analyses) lightning activity of each of the routes can be thoroughly studied. By so doing, designers will be able to predict lightning activity in the various routes and select the one that will have fewer problems (or require less intervention as far as mitigatory measures against lightning are concerned).

This consequently has a huge impact on ensuring that minimization of lightning related faults on the transmission line gets done upfront, instead of during the operating life of the plant, which could be very costly, not only to Eskom but to its clients also.

4.2 Lightning Performance analysis during design

Prior to the use of FALLS, information regarding lightning activity at an area was based on the ground flash density map and the utility's fault records. Use of FALLS allows designers to look into various areas of the line route and using the strokes density, areas with high lightning activity can be studied better and predict what the expected performance of lines will be with the use of Tools such as T-Flash. This ensures that traverse very high lightning prone areas with high ground flash densities can be designed incorporating solutions to mitigate against lightning faults. This practice is better than only identifying problem areas during the operational phase of the line as mitigatory measures may be more costly.

4.3 Asset Management – Existing Lines

The aim of asset management is to ensure that plant performs its task as per its design specifications. Part of asset management is performance management, which looks at the above and addresses any deviations from the set performance targets by the asset. Utilities spend millions of rands on performance management programs for their assets.

4.3.1. Fault Correlation

When a fault has occurred on a line, it must be classified, either as a Bird, Fire, Lightning or design related fault, amongst other categories. Faults that are suspected to have been caused by lightning were usually difficult to prove and if there were storms or lightning seen in that area before the fault, it was automatically assumed that lightning was the cause.

The concern with misdiagnosis is that the utility winds up spending its resources on "causes" that may not necessarily improve the performance of the asset.

The use of FALLS is also to confirm lightning activity at a specific area, at a specific time, known as fault correlation.
The example below illustrates a case where FALLS was used for fault correlation.

A specific 275kV Eskom line was identified as having continuous lightning related faults and towards the end of 2005 a study was commissioned to look at possible use of TLSA's to improve this line's performance [3]. The TLSA were installed end of 2005 and a review of the line's performance was done in 2009 to check the effectiveness of the solutions.

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Eskom's newly acquired FALLS was used as means of correlating first and foremost the faults experienced during the period after the TLSA installation and also, as an estimate of possibly how many more faults could have occurred should the TLSA not been installed.

Figure 3 below shows the lightning performance of the line in question until the end of 2005.

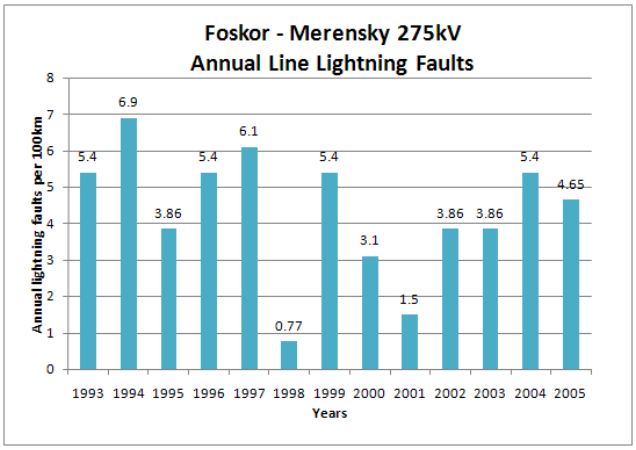

Figure 3: Annual line lightning faults per 100km

Figure 4 below shows the general performance of the line since the installation of the TLSA. It should be noted that these faults are generally reported faults without the use of a lightning location system to verify their authenticity.

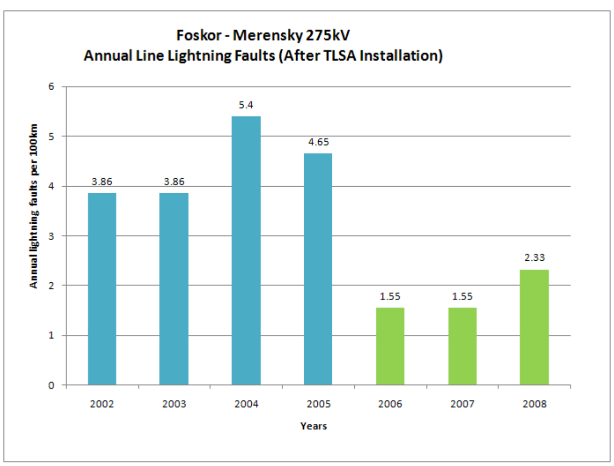

Figure 4: General performance of the line before and after TLSA installation (per 100km/annum)

- **General Performance Review as part of asset management**

The performance review was carried out in 2 parts; one part looked at general overall lightning performance of the line and compared the current overall performance of the line with what was predicted i.e. 1.212 faults/100km/annum [4].

The second part looked at fault correlation with the use of FALLS in investigating these faults and checked whether they occurred within the area where the TLSA were installed and whether the TLSA were effective or not. Figure 4 below shows one of the FALLS correlation analysis that was done.

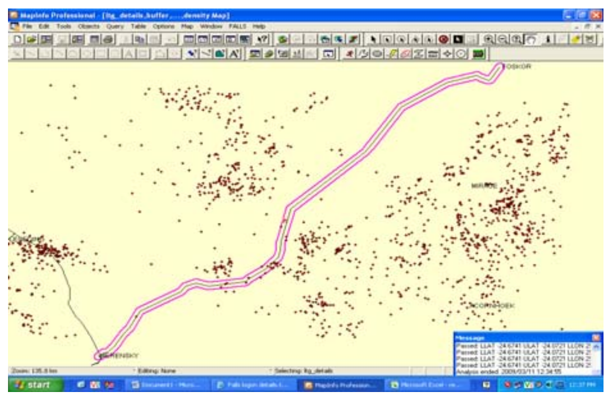

Figure 5: April 2006 lightning Activity

Looking at the line's lightning performance prior and after the installation of the TLSA i.e. from 2006 until 2008, their average showed an improvement of 61%. This value is without verification with the use of the lightning location system.

This improvement shows the effectiveness of the installation already by the virtue of this drop in lightning related faults on this line.

- **Performance Improvement review with the use of FALLS as part of Asset management**

The incidents that were categorized as lightning related by the grid are referred to as cases below.

The 2006 FALLS correlation shows for case 1 that there was no correlation and this would imply that according to FALLS this fault didn't take place. While the correlation for case 2 correlated a -31 kA nearby stroke close to tower 200. Whether it was high enough to cause an induced flashover on a 275kV line was questionable.

The 2007 FALLS correlation for case 1 is a -13kA close to tower 240 and its magnitude was too low to cause an induced flashover on a 275kV line as this tower's measured tower footing resistance was 12 ohms which is low to have made the tower to have an induced flashover from a stroke of such a magnitude. Case 2 was correlated with a nearby stroke of -19kA stroke in the region of tower 243 which also had a very low tower footing resistance of close to 5 Ohms and could not have caused an induced flashover on this tower.

2008 FALLS Correlated case 1 to a -52kA nearby stroke which was assumed could have caused an induced flashover. Case 2 was correlated to a -71kA nearby stroke close to tower 140 which also could have caused an induced flashover as this region also doesn't have TLSA. Case 3 was also correlated to a -13kA nearby stroke which would have been too low to cause an induced flashover to any of the structures in its vicinity.

According to FALLS correlation, the line's performance improvement is 83% instead of the reported 61%.

4.3.2 Lightning Performance Improvement – Mitigation as part of Asset management

Lightning performance improvement, as already discussed above, could also be done through the use of Transmission Line Surge Arresters, as done on the line studied above. The use of FALLS on this line's performance review has allowed the designers to be able to review whether the selection of the ratings of the TLSA installed on this line was correct or not.

FALLS could avail all the various current magnitudes that the line's buffer zone was subjected to in order to be able to check the energy capabilities of the TLSA and hence being able to review whether the design assumptions during the development of the mitigation strategy were realistic or not.

4 CONCLUDING REMARKS AND RECOMMENDATIONS

FALLS has, within a very short time period of application in Eskom shown positive benefits as the paper has shown above. Its use in the route selection process, design stages of transmission lines and the investigations of performance of already existing lines is becoming more effective. As users of the tool, there are opportunities that have been identified for improvement of the tool in areas such as following:

- A more automated means of generating Stroke Density Maps for ease of exporting to T-Flash for area analysis

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- Ability for the sensors to capture the actual lightning waveforms, so as to be able to do detailed incident investigations with representative waveforms, not generic ones.

REFERENCES

[1] FALLS Client User Guide version 3.2 August 2004

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[3] F. Mokhonoana, L Peter “*Review of Lightning Performance Improvement Project Results: A Case Study from South Africa*” CIGRE 2009,

[4] L. Peter, “*Use of Line Surge Arresters to improve Lightning performance of a 275kV line: A South African Pre-Engineering Case Study*”, ICLP 2006, Kanazawa

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