

In-Situ Monitoring of Leakage Current on Composite and Glass Insulators of the Cahora Bassa HVDC Transmission Line

Morné Roman, Robert R. van Zyl, Nishanth Parus and Nishal Mahatho

Abstract—High voltage transmission line design requires careful insulator selection to ensure good operational performance. This paper reports on the in-situ measurements of leakage current (LC) on composite and glass insulators of the Cahora Bassa high voltage direct current (HVDC) transmission line in South Africa over a 6-month period. The influence of temperature, humidity, dew, rain and the HVDC line's voltage and current on LC are investigated. The results show that the composite and glass insulator LC behaviour is similar, except in cases of high humidity or rain. At the commencement of rainfall and humidity (>90%), elevated LC levels are observed on glass insulators, while composite insulators demonstrate lower LC levels under these conditions. Under nominal weather conditions of no rain and low humidity, the LC measurements exhibit an almost square-wave behaviour with LC switching between lower ($\approx 20 \mu\text{A}$) and higher values ($\approx 60 \mu\text{A}$) with relatively short transitions on a daily basis. This phenomenon can be ascribed to condensation on the insulators, which is a primary determinant of the LC levels on contaminated insulators. The line current and voltage fluctuations do not influence the LC level.

Index Terms—High voltage direct current, insulator, leakage current, transmission lines

I. INTRODUCTION

INSULATORS play a significant role in overhead transmission lines and substations [1]. Faults on insulators caused by lightning, pollution and contamination influence the

The financial support of the National Research Foundation and Eskom Research, Testing and Development department towards this research is acknowledged.

M. Roman is with the Department of Electrical, Electronic and Computer Engineering, Cape Peninsula University of Technology, Cape Town, South Africa (e-mail: romanm@cput.ac.za).

R. R. van Zyl is with the Department of Electrical, Electronic and Computer Engineering, Cape Peninsula University of Technology, Cape Town, South Africa (e-mail: vanzylr@cput.ac.za).

N. Parus is with the Research, Testing & Development Department, Eskom Holdings SOC Ltd, Johannesburg, South Africa (e-mail: nishanp@eskom.co.za).

N. Mahatho is with the Research, Testing & Development Department, Eskom Holdings SOC Ltd, Johannesburg, South Africa (e-mail: mahathn@eskom.co.za).

efficiency of transmission lines [2]. Elevated leakage current (LC) levels on insulators may be indicative of inferior contamination performance of an insulator string, which may lead to faults, such as flashover [3], [4], [5]. This is especially relevant along coastal areas. Studying LC in real-time can be used as an early warning tool against line faults caused by insulators, as well as classifying safe and unsafe working conditions for the power utilities' live line workers. LC can also be used to classify stages leading up to flashover; Li *et al.* divide the buildup of LC into a security stage, forecast stage and danger stage [6]. Roman *et al.* discusses the benefits of monitoring insulator LC in detail [7].

This paper reports on the LC measurement obtained over a 6-month period on the Cahora Bassa high voltage direct current (HVDC) transmission line at the Apollo converter station in Gauteng, South Africa, which is rated at $\pm 533 \text{ kV}$. This deepens our understanding of LC behaviour on insulators under HVDC conditions, at least at high altitudes, since published data of LC levels on in-service HVDC transmission line insulators are limited. Laboratory pollution flashover experiments for HVDC insulators do state that there is a higher probability of flashover occurrence at higher altitudes compared to that at sea level [10], [11], [12]. In this paper, the LC of a composite and glass string, configured in an inverted-V, has been measured with shunt resistors.

II. LEAKAGE CURRENT ON INSULATORS

Dry-band arcs and possible flashover on insulators are exacerbated by light rain and high humidity conditions [13], [14], [15]. Werneck *et al.* states the conditions that lead to flashover [16]:

- Pollutants settle on the surface of the insulator;
- These deposits combine with moisture caused by light rain, fog, mist or dew and form a conductive layer on the insulator's surface;
- LC starts to flow;
- Partial discharges start occurring on the insulator's surface;
- Possible flashover.

A. Types of Insulators

Insulators are made from various materials. For the work presented here, glass (ceramic) and composite (polymeric) insulators are investigated.

A composite insulator consists of at least two insulating parts; a fibre glass core and metal end fittings [17]. Benefits of composite insulators, when compared to ceramic insulators, are improved contamination performance, the hydrophobicity of their surfaces and lighter weight [18]. Disadvantages of composite insulators are that they suffer from surface erosion and tracking that may lead to insulator failure. On HVDC lines, there is a reluctance to use composite insulators, since there is no IEC standard regarding their use on these lines [18].

Glass insulators consist of a glass shell that is cemented between an iron cap and steel pin end fittings. Glass insulators have high mechanical strength and operational lifetimes exceeding 50 years, which is advantageous [19]. A disadvantage of glass insulators is their susceptibility to vandalism.

B. Insulator contamination

Contamination of insulator surfaces can be attributed to pollution, dust and ambient salt content [8]. High ambient humidity conditions and contamination of these surfaces, increase the probability and levels of LC activity. Surface tracking is another form of pollution of insulators, where the formation of carbon tracks lead to increased LC. Flashovers are present in both HVAC and HVDC transmission line systems, but in some respect, their responses are fundamentally different. Some of the different responses are listed below [12], [20], [21], [22], [23]:

- The process of contaminant build-up is different, with insulators in HVDC transmission line systems accumulating more pollution than compared to their HVAC counterparts.
- There are no current and voltage zeroes in a DC transmission system, which aggravates the flashover problem. Thus, scintillations are more difficult to suppress on HVDC insulators.
- An insulator with the same pollution severity will have a lower flashover voltage for DC than AC.

C. LC monitoring on HVAC insulators

LC monitoring on HVAC transmission line insulators has been covered extensively in literature. Zachariades *et al.* performed LC measurements on two composite insulating cross arms energised at 231 kV [9]. Meyer *et al.* monitored 25 kV ceramic post line insulators in urban and rural areas. LC was collected by a metal ring and fed to a shunt resistor [14]. Werneck *et al.* used a fibre optic sensor for real-time composite insulator LC monitoring on a 500 kV line [16]. Sierra *et al.* measured LC on a 220 kV ceramic insulator using a current transformer (CT) [24]. Oliviera *et al.* used a fibre optic sensor on a 230 kV tower, 500 kV and 230 kV substation for insulator LC monitoring [25]. All of the authors measured the LC against climatic conditions, especially humidity. It was found that high humidity levels increase LC activity.

D. LC monitoring on HVDC insulators

Little information is available in literature on the behaviour of LC on HVDC transmission insulators, and the methods to perform in-situ LC measurements on energised insulators in the field. Furthermore, some conventional methods used in measuring LC in HVAC systems, such as a current transformer, are unsuitable for DC measurements as there are no alternating magnetic fields coupling into the device. A resistive shunt and an online leakage current analyser (OLCA) can detect AC and DC LC. With an OLCA, a glass stand-off insulator is normally installed in series at the ground-end of the insulator under test [26], [27].

The authors have previously shown that magnetic field sensors can be used to detect LC on insulators. The magnetic field sensors used were fluxgate and magnetoresistive magnetometers, which are described in [28], [29].

The resistive shunt method is used in this paper.

III. HVDC INSULATOR LC FIELD TESTS

A. Monitoring and analyses method

A glass and composite insulator have been installed on the terminal tower of the Cahora Bassa HVDC transmission line located at the Apollo Converter Station in Johannesburg, South Africa as shown in Fig. 1. The insulator strings' unified specific creepage distance (USCD) at Apollo is approximately 40 mm/kV and the equivalent salt deposit density (ESDD) at Apollo is 0.03 mg/cm² [30]. This setup presents a controlled environment where the composite and glass insulators are on the same inverted-V string and exposed to the same environmental conditions; thus, their LC behaviour can be reliably compared.

A 10 Ω shunt resistor is placed on the composite and glass insulator strings to measure the LC. The measurement setup comprises a data logger, two 12 V batteries, and two solar panels. LC is sampled and logged at 10-second intervals. The ambient climatic data is logged at 6-minute intervals at a station installed less than a kilometre away.

The measured LC datasets have been analysed on a weekly basis against ambient temperature, humidity, dew, rain, and the HVDC line's voltage and current. For analysis purposes, the *maximum* measured LC and climatic parameters over successive hourly intervals are considered. Most of the data have been collected in the spring-summer season (Southern Hemisphere), which is the rainy season.

B. LC activity over six-month period

LC has been measured over a six-month period starting from August 2016 to February 2017. Due to the huge amount of data, this paper only presents certain weeks where increased LC activity has been observed.

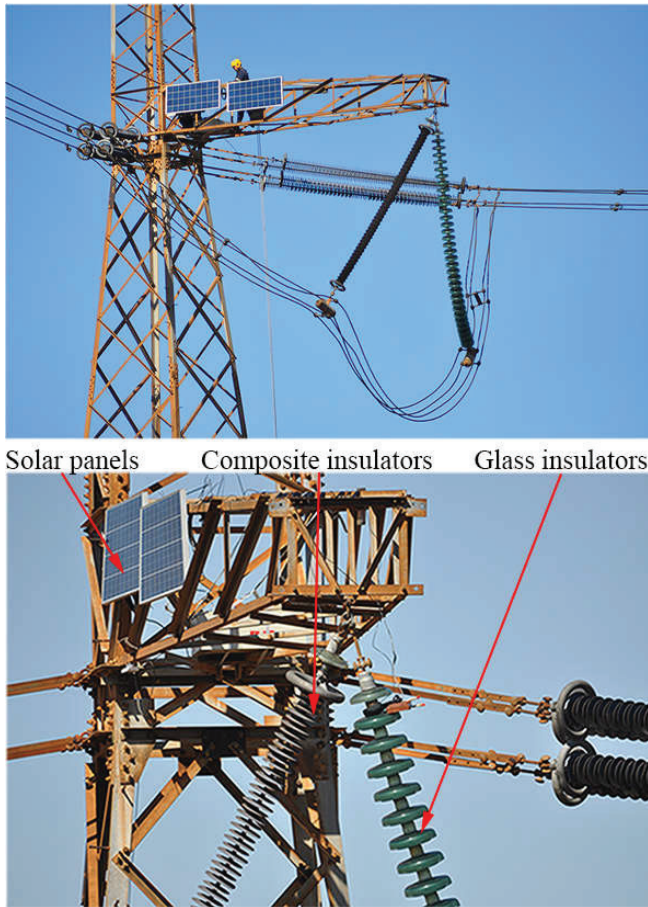


Fig. 1. Inverted-V insulator string used in HVDC insulator LC field tests on the Cahora Bassa transmission line.

1) August 3rd - 9th:

Fig. 2 shows the LC activity from the 3rd to the 9th of August with its corresponding HVDC line current and voltage. The weather conditions for the same period are presented in Fig. 3. It is evident that LC for both the glass and composite insulators behave similarly, except under high humidity conditions. The nominal LC varies between 20 μ A and 60 μ A under low humidity conditions, which are well within the acceptable range for good performing insulators as discussed in Ferreira *et al.* [9]. On the 9th of August, the LC rises above 5 mA in high humidity conditions on the glass insulator. The line current and voltage fluctuations do not influence the nominal LC levels. This is an observation that applies throughout the 6-month field test. Between the 4th and 5th of August, LC was present but no line voltage and current data were available from Apollo.

2) September 14th - 20th

Fig. 4 shows the LC activity from the 14th to the 20th of September with its corresponding HVDC line current and voltage. Fig. 5 shows the weather conditions for the same period. On the 18th of September, the ambient temperature was at its lowest for the week, humidity was above 90% and rain was present. These conditions have given rise to an increase in LC of just over 0.6 mA on the glass insulator with

the commencement of rain. However, during the same timeframe, the composite insulator experienced even lower than usual LC, behaving completely opposite to the glass insulator. This can be ascribed to the composite insulator exhibiting its hydrophobicity properties.

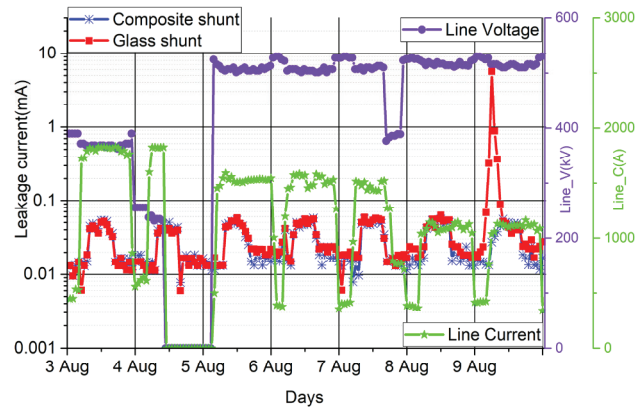


Fig. 2. Leakage current activity: 3rd - 9th of August

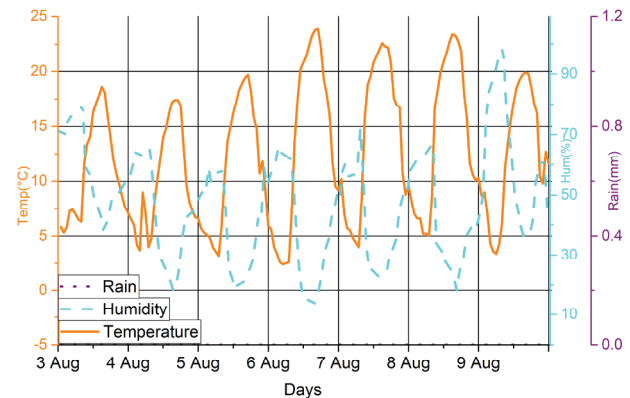


Fig. 3. Weather conditions: 3rd - 9th of August

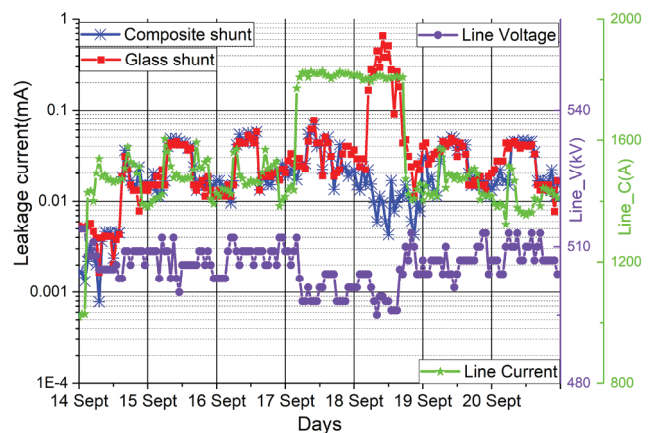


Fig. 4. Leakage current activity: 14th - 20th of September

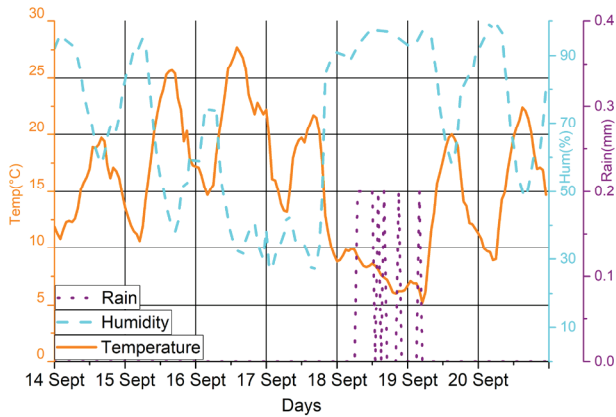


Fig. 5. Weather conditions: 14th - 20th of September

3) November 7th - 13th

Fig. 6 shows the LC activity between the 7th and 13th of November with its corresponding HVDC line current and voltage. Fig. 7 shows the weather conditions for the same period. On the 9th of November, when high rainfall commenced, the LC on the glass insulator increased. Incidentally, during this week and especially on the 9th of November, flash floods occurred in Johannesburg [31], which lead to the high rainfall measured.

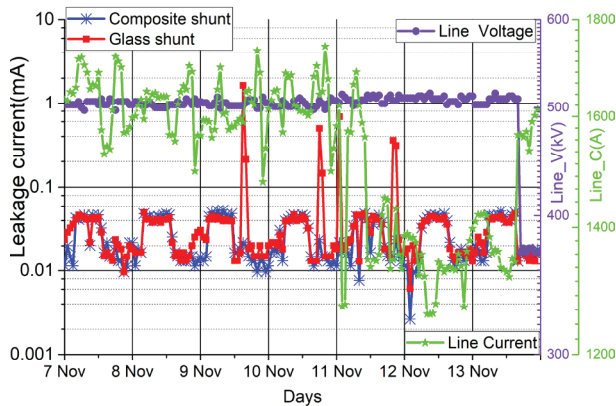


Fig. 6. Leakage current activity: 7th - 13th of November

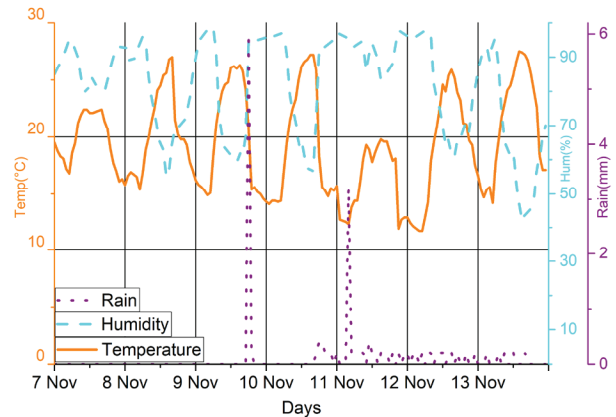


Fig. 7. Weather conditions: 7th - 13th of November

4) December 8th - 14th

Fig. 8 shows the LC activity between the 8th and 14th of December. No HVDC line voltage and current was obtainable at Apollo since the beginning of December 2016. Thus, the LC results are presented without it. Fig. 9 shows the weather conditions for the same period. On the 10th of December, when rainfall commenced, an increase in LC was observed on the glass insulator. No elevated LC activity was seen on the composite insulator during the same timeframe.

5) December 29th - January 4th

Fig. 10 shows the LC activity between the 29th of December - 4th of January. Fig. 11 shows the weather conditions for the same period. During the evening, on the 3rd of January, increased LC was observed on the glass insulator. This increase coincided again with the commencement of rainfall and high humidity. No increased LC behaviour was observed on the composite insulator.

During the measurement period it was observed that increased LC activity normally takes place late evening to early morning when temperature is at its lowest and humidity at its highest. This is in agreement with the HVAC insulator LC measurements performed in [9], [14], [15], [16].

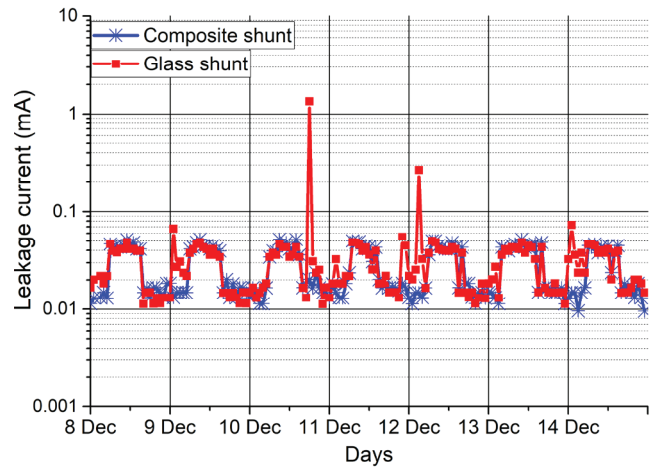


Fig. 8. Leakage current activity: 8th - 14th of December

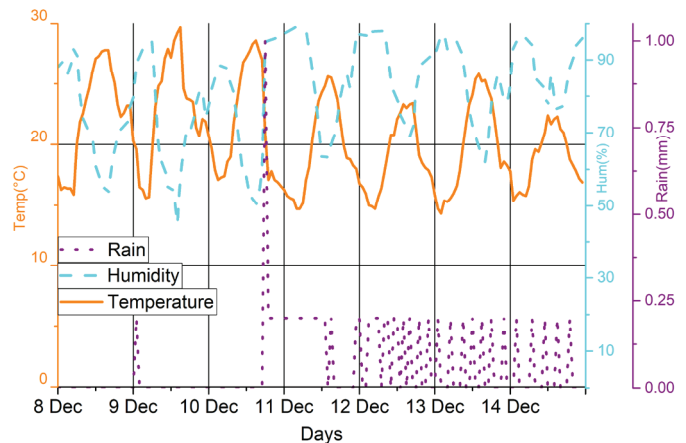


Fig. 9. Weather conditions: 8th - 14th of December

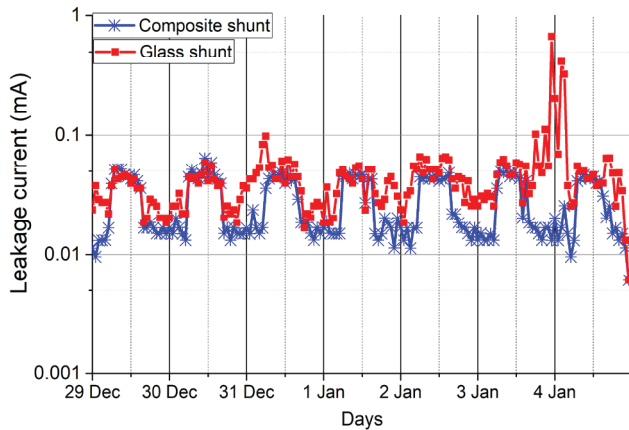


Fig. 10. Leakage current activity: 29th of December - 4th of January

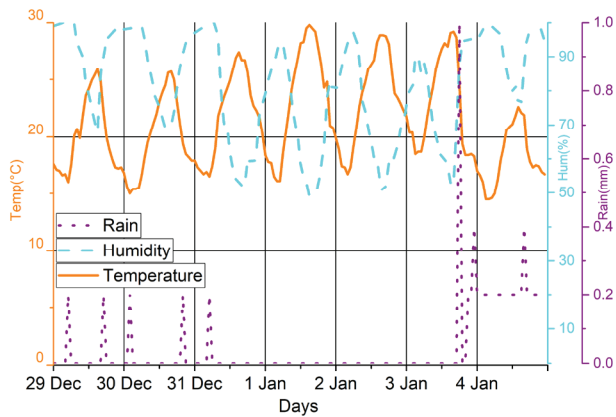


Fig. 11. Weather conditions: 29th of December - 4th of January

Pigini *et al.* performed a statistical evaluation of the polluted performance of composite and glass insulators under DC stress [20]. It was observed that the risk of flashover for a 40 mm/kV insulator string with an ESDD of 0.05 mg/cm² was less than 1%. This agrees well with the low LC levels seen on the Cahora Bassa line. Literature mentions that the composite insulators have superior performance over glass insulators under DC energisation, which was also observed in this paper [11], [12], [23], [32].

C. Effect of condensation on LC

Interestingly, under nominal weather conditions of no rain and low humidity, the LC measurements exhibit an almost square-wave behaviour with LC switching between lower and higher values with relatively short transitions on a daily basis. This behaviour cannot be explained directly in terms of the ambient humidity and temperature, as these parameters display more gradual daily temporal cycles. It can also not be ascribed to fluctuations in the line current or voltages, as these have been found to have little or no correlation with the LC behaviour.

This has lead to the investigation of the possible effect of the ambient *dew point*, and the corresponding occurrence of condensation, on the LC.

Fig. 12 shows the composite and glass insulator LC along with the difference between the ambient temperature (T) and dew point temperature (T_d) from the 3rd to the 8th of August. The 9th of August has been omitted, as very high humidity conditions were present on the day.

It is evident that as soon as the ambient temperature approaches the dew point temperature (where the likelihood of condensation on the insulators is high), a sharp rise in the nominal LC is triggered. On the other hand, when the difference between the ambient temperature and the dew point temperature is at its highest (where the likelihood of condensation on the insulators is low), the LC falls quickly. Hence, it can be deduced that condensation triggers the sharp daily rise and fall of LC between its nominally low and high values of 20 μ A and 60 μ A, respectively. A similar trend has been observed throughout the measurement period, although not presented here.

IV. CONCLUSION

Shunt resistors were placed on a composite and glass HVDC insulator string and left in the field for 6 months to conduct insulator LC measurements. During this period, when no rain and relatively low humidity conditions were present, the LC for both the glass and composite insulators behave similarly. High humidity and the onset of rain raise the nominal LC levels on the glass insulator, whereas rain has had the opposite effect on the composite insulator's LC. Condensation on the insulators has been shown to be a primary determinant of the LC levels on the insulators. The line current and voltage fluctuations do not influence the LC levels. The nominal LC over the 6-month test period varies between 20 μ A and 60 μ A, which is in agreement with optimally performing insulators.

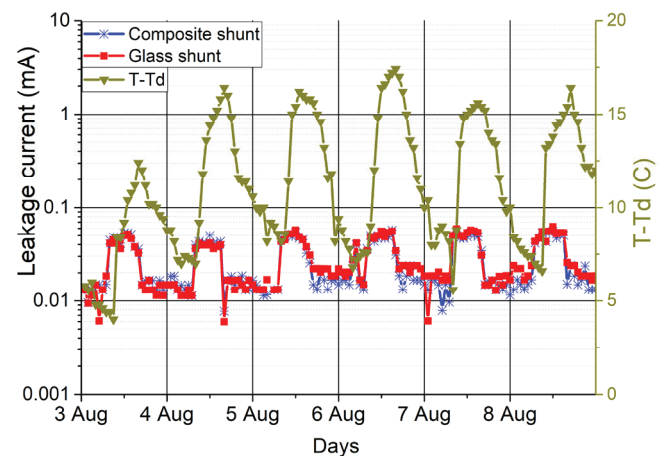


Fig. 12. Leakage current activity with difference between temperature and dewpoint ($T-T_d$): 3rd - 8th of August

It is recommended to continue the LC measurements to account for seasonal variations and anomalies. This will provide a better understanding of LC activity when seasonal variations are taken into account as well.

V. REFERENCES

- [1] D. Pylarinos, K. Siderakis, E. Pyrgioti, "Measuring and analysing leakage current for outdoor insulators and specimens", *Rev. Advanced Materials Sci.*, vol. 29, no. 1, pp. 31-53, 2011.
- [2] W. K. Glossop, "Performance comparison of existing ac and dc transmission lines within Southern Africa with predictions for lines above 765kv", M.S. thesis, Dept. Eng. and built environment, Univ. of Witwatersrand, Johannesburg, 2008.
- [3] N. Mavrikakis, M. Kapellakis, D. Pylarinos *et al.*, "A novel autonomous monitoring system for distributed leakage current measurements on outdoor high voltage insulators", [Online]. Available: <http://trivent-publishing.eu/pdfdownload/12.NikolaosMavrikakis.pdf>
- [4] L. Holtzhausen, J. P. Pieterse, H. J. Vermeulen *et al.*, "Insulator aging tests with HVAC and HVDC excitation using the tracking wheel tester", in *ICHVE 2010*, New Orleans, LA, USA, pp. 445-448, October 2010.
- [5] W. H. Schwardt, J. P. Holtzhausen, W. L. Vosloo, "A Comparison between measured leakage current and surface conductivity during salt fog tests", in *7th Africon*, Gaborone, Botswana, pp. 597-600, September 2004.
- [6] J. Li, W. Sima, C. Sun, S. A. Sebo, "Use of leakage currents of insulators to determine the stage characteristics of the flashover process and contamination level prediction", *IEEE Trans. Dielectrics and Electrical Insulation*, vol. 17, no. 2, pp. 490-501, April 2010, DOI: 10.1109/TDEI.2010.5448105.
- [7] M. Roman, R. R. van Zyl, N. Parus *et al.*, "Insulator leakage current monitoring: challenges for high voltage direct current transmission lines", in *ICUE 2014*, Cape Town, South Africa, pp. 1-7, August 2014, DOI: 10.1109/ICUE.2014.6904201.
- [8] K. V. Thejane, M. D. Ntshani, H. J. Geldenhuys *et al.*, "Effect of insulator application on the leakage current performance of woodpole distribution line structures", in *Proc. of the 18th ISH*, Seoul, Korea, pp. 1223-1227, 2013.
- [9] T. V. Ferreira, A. D. Germano, E. G. da Costa *et al.*, "Naturally aged polymeric insulators: washing and its consequences", *Proc. of the International Symposium of Modern Electric Power Systems*, Wroclaw, Poland, pp. 1-5, 2010.
- [10] L. Yang, Y. Hao, L. Li, "Comparison of Pollution Flashover Performance of Porcelain Long Rod, Disc Type, and Composite UHVDC Insulators at High Altitudes", *IEEE Trans. on Dielectrics and Electrical Insulation*, vol. 19, no. 3, pp. 1053-1059, June 2012, DOI: 10.1109/TDEI.2012.6215112.
- [11] X. Yu, Q. Zhang, H. Yang *et al.*, "Leakage current characteristics of long insulator string during DC pollution flashover test under various air pressures", in *CMD*, Xi'an, China, pp. 481-484, 2016, DOI: 10.1109/CMD.2016.7757866.
- [12] F. Zhang, J. Zhao, L. Wang, "Experimental investigation on outdoor insulation for DC transmission line at high altitudes", *IEEE Trans. on Power Delivery*, vol. 25, no. 1, pp. 351-357, 2010, DOI: 10.1109/TPWRD.2009.2034889.
- [13] C. Zchariades, S. M. Rowland, I. Cotton, "Real-time monitoring of leakage current on insulating cross-arms in relation to local weather conditions", *Electrical Insulation Conference*, Ottawa, Canada, pp. 397-401, June 2013.
- [14] L. H. Meyer, C. R. P. Oliboni, T. I. A. H. Mustafa *et al.*, "A study of the correlation of leakage current, humidity and temperature of 25 kV insulators in urban and rural areas", in *CEIDP*, Cancun, Mexico, pp. 398-402, October 2011, DOI: 10.1109/CEIDP.2011.6232679.
- [15] Suwamo, J. Parhusip, "Effects of humidity and fog conductivity on the leakage current waveforms of ceramics for outdoor insulators", *WSEAS transaction on systems*, vol. 9, issue 4, pp. 442-452, 2010.
- [16] M. M. Werneck, D. M. dos Santos, C. C. de Carvalho *et al.*, "Detection and monitoring of leakage currents in power transmission insulators", *IEEE sensors journal*, pp. 1-9, 2014, DOI: 10.1109/TPWRD.2009.2016814.
- [17] M. T. Gencoglu, "The comparison of ceramic and non-ceramic insulators", *New world sciences academy*, vol. 2, no. 4, pp. 1-21, 2007.
- [18] M. Costea, I. A. Baran, "Comparative analysis of classical and composite insulators behaviour", *Science bulletin*, vol. 74, no. 1, pp. 1-8, 2012.
- [19] J. P. Holtzhausen, "High voltage insulators", [Online]. Available: http://www.idc-online.com/technical_references/pdfs/electrical_engineering/highvoltage.pdf
- [20] A. Pigini, R. Cortina, "Evaluation of the performance of polluted insulators under DC: A statistical approach", in *Proc. of the 17th ISH*, pp. 1-6, August 2011.
- [21] T. C. Cheng, C. T. Wu, F. Zedan *et al.*, "EPRI - HVDC insulator studies: part i field test at the sylmar HVDC converter station", *IEEE Transactions on Power Apparatus and Systems*, vol. 100, no. 2, pp. 902-909, 1981.
- [22] C. S. Engelbrecht, J. P. Reynders, A. C. Britten *et al.*, "Outdoor insulation in polluted conditions: Guidelines for selection and dimensioning. Part 2: The DC case", *CIGRE WG C4.303*, pp. 9-12, 2012.
- [23] X. Jiang, J. Yuan, L. Shu *et al.*, "Comparison of DC pollution flashover performances of various types of porcelain, glass, and composite insulators", *IEEE Trans. on Power Delivery*, vol. 23, no. 2, pp. 1183-1190, 2008, DOI: 10.1109/TPWRD.2007.908779.
- [24] R. C. Sierra, O. Oviedo-Trespalacios, J. E. Candelo *et al.*, "The influence of atmospheric conditions on the leakage current of ceramic insulators on the Colombian Caribbean coast", *Springerlink Environmental Science and Pollution Research*, vol. 22, no. 4, pp. 2526-2536, 2015, DOI: 10.1007/s11356-014-3729-3.
- [25] S. C. Oliveira, E. Fontana, F. Cavalcanti, "Leakage Current Activity on Glass-Type Insulators of Overhead Transmission Lines in the Northeast Region of Brazil", *IEEE Trans. on Power Delivery*, vol. 24, No. 2, pp. 822-827, 2009, DOI: 10.1109/TPWRD.2008.2002872.
- [26] P. J. Pieterse, A. I. Elombo, G. N. J. Mouton *et al.*, "A coastal insulator pollution test station for the evaluation of the relative ageing performance of power line insulators under AC and DC voltage", in *Proc. of the 17th ISH*, C-007, pp. 1-5, August 2011.
- [27] A. I. Elombo, J. P. Haultzhausen, H. J. Vermeulen *et al.*, "Comparative evaluation of the leakage current and aging performance of HTV SR insulators of different creepage lengths when energised by AC, DC+, DC- in a severe marine environment", *IEEE Trans. on Dielectrics and Electrical Insulation*, vol. 20, issue 2, pp. 421-428, 2013, DOI: 10.1109/TDEI.2013.6508743.
- [28] M. Roman, R. R. van Zyl, N. Parus *et al.*, "A novel technique for measuring HVDC insulator leakage current using magnetic field sensors", in *Proc. of the 19th ISH*, http://www.zcu.cz/pracoviste/vyd/online/FEL_ISH_2015_Proceedings.zip, OF1, ID-36, pp. 1-6, 2015.
- [29] M. Roman, R. R. van Zyl, N. Parus *et al.*, "The measurement of HVDC insulator leakage current using magnetic field sensors", [Online]. Available: <http://www0.sun.ac.za/saupec2017/Papers/PaperView.php?%20PublicationID%20=%201554>
- [30] S. Narain, V. Naidoo, R. Vajeth, "Upgrading the performance of the Apollo - Cahora Bassa 533kV links", *CIGRE 2012*, B2-301, pp. 1-8, 2012.
- [31] News24. "News24 - 21 unbelievable photos and videos of Joburg's flash floods", [Online]. Available: <https://www.news24.com/You/Archive/21-unbelievable-photos-and-videos-of-joburgs-flash-floods-20170728>
- [32] A. Abbasi, A. Shayegani, K. Niayesh, "Pollution Performance of HVDC SiR Insulators at Extra Heavy Pollution Conditions", *IEEE Trans. on Dielectrics and Electrical Insulation*, vol. 21, no. 2, pp. 721-728, 2014, DOI: 10.1109/TDEI.2013.003990.



Morné Roman was born in Cape Town, South Africa, on January 14, 1988. He graduated from Bishop Lavis High School, and studied at the Cape Peninsula University of Technology.

His employment experience included GrandWest Casino, MEDO and Africa Space Innovation Centre. His special fields of interest included high voltage direct current transmission lines and satellite engineering.

Mr Roman received his ND, BTech Cum Laude and MTech Cum Laude degrees in 2008, 2010 and 2012 respectively at the Cape Peninsula University of Technology (CPUT). He also received an MSc. degree in electronic and electrical systems at École Supérieure d'Ingénieurs en Électronique et Électrotechnique (ESIEE) in 2012.



Nishanth Parus received his MSc. (Eng.) degree from the University of the Witwatersrand, Johannesburg, in 2014. He is currently working as a Senior Researcher at Eskom's Research, Testing and Development department. His areas of focus are high voltage transmission line design, electrical corona, drones and computer vision. Mr Parus is responsible for the operations at Eskom's corona cage test facility. He is a Senior Member of the South African Institute of Electrical Engineers (SAIEE) and is registered as a Professional Engineering Technologist with the Engineering Council of South Africa (ECSA). Mr Parus has served as the South African or Eskom representative on various international working groups of Cigré and the Electrical Power Research Institute (EPRI), USA.



Robert van Zyl studied at the University of Stellenbosch where he obtained his Bachelor, Master's and Doctorate degrees in Electronic Engineering. He is the Director of the French South African Institute of Technology and the Africa Space Innovation Centre at the Cape Peninsula University of Technology (CPUT). The research group is developing nano-satellite technology and applications for socio-economic development in Africa. Under his direction, a team of students and

engineers have developed Africa's first nano-satellite which was launched in 2014. His other professional interests include electromagnetic compatibility studies, as well as high-frequency semiconductor device simulation.



Nishal Mahatho holds a Master of Science in Electrical Engineering from the University of Witwatersrand, Johannesburg. He is in the employment of Eskom, Research, Testing & Development since 1996 and currently holds the position of Senior Specialist, specialising in insulator research, line design, system performance, UAV and robotics inspections. He is currently developing Eskom's 1.2 MV and 1 MV Bipolar HVDC Research & Testing Facilities – the first in Africa and the

Southern Hemisphere. He is a member on a number of Cigré working groups, and is convener of WG D1.61 - Optical corona detection and measurement. He has authored a number of national and international papers, is an active IEEE reviewer, and was a Member of Council and currently Senior Member of the South African Institute of Electrical Engineers (SAIEE).