Article de recherche

Rev. Cong. Sci. Technol., Vol. 04, No. 04, pp. 832-839 (2025)

OPEN ACCESS

Revue Congolaise des Sciences & Technologies

ISSN: 2959-202X (Online); 2960-2629 (Print)

https://www.csnrdc.net/

REVUE CONGOLAISE DES SCIENCES ET TECHNOLOGIES

Statistical analysis test of voltage variations on power Transformers in the city of Boma, Democratic Republic of the Congo

[Test d'analyse statistique des variations de tension sur les transformateurs de puissance de la ville de Boma, République Démocratique du Congo]

Mampuya Nzita André[1,2,*], Kumbu Tenda André-Pachely[1], Mwanda Mizengi Léon[2], Biabia Mumpele Popol[2], Wanlogo Ndiwulu Guy[3], Dituba Ngoma Guyh[4] & N'zau-di-Mbudi Clemént [1,5]

[1]*President Joseph Kasa-Vubu University, Faculty of Engineering, Boma, Democratic Republic of the Congo*
[2]*Regional School of Water (ERE), University of Kinshasa (UNIKIN), Kinshasa, Democratic Republic of the Congo*
[3]*Department of Electrical Engineering, Polytechnic Faculty, University of Kinshasa, Democratic Republic of the Congo*
[4]*University of Quebec in Abitibi-Temiscamingue, School of Engineering, Rouyn-Noranda, Canada*
[5]*University of Kinshasa, Faculty of science and technology, Kinshasa, Democratic Republic of the Congo*

Abstract

This study examines voltage variations in customer feeders and their impact on the performance of electrical transformers in the city of Boma, Democratic Republic of Congo. The research was motivated by a lack of in-depth analysis on the effects of voltage fluctuations on transformer reliability. To do this, an analysis of variance was performed using six transformers and voltage measurements taken on twenty-nine lines. The results showed a significant diversity of voltage levels, ranging from 127 to 195 volts, and confirmed that voltage variations affect transformer performance. It is recommended to install real-time monitoring systems and adapt transformer designs to local specificities. This study highlights the importance of rigorous voltage management to prevent outages and improve the reliability of the electrical network.

Keywords : Voltage variations, Transformers, ANOVA, preventive maintenance, Energy management.

Résumé

Cette étude examine les variations de tension dans les lignes d'alimentation des clients et leur impact sur la performance des transformateurs électriques de la ville de Boma, en République démocratique du Congo. Cette recherche a été motivée par le manque d'analyse approfondie des effets des fluctuations de tension sur la fiabilité des transformateurs. Pour ce faire, une analyse de variance a été réalisée sur six transformateurs et des mesures de tension ont été effectuées sur vingt-neuf lignes. Les résultats ont montré une diversité significative des niveaux de tension, allant de 127 à 195 volts, et ont confirmé l'impact des variations de tension sur la performance des transformateurs. Il est recommandé d'installer des systèmes de surveillance en temps réel et d'adapter la conception des transformateurs aux spécificités locales. Cette étude souligne l'importance d'une gestion rigoureuse de la tension pour prévenir les pannes et améliorer la fiabilité du réseau électrique.

Mots-clés: Variations de tension, transformateurs, ANOVA, maintenance préventive, gestion de l'énergie.

*Auteur correspondant : Mampuya Nzita André(simmlicem57@gmail.com). Tél. : (+243) 99 93 402 14
https://orcid.org/0009-0007-6092-145X
Reçu le 08/12/2025 ; Révisé le 22/12/2025 ; Accepté le 05/01/2026
DOI : https://doi.org/10.59228/rcst.025.v4.i4.208

1. Introduction

This study focuses on operational problems encountered by transformers installed in the city of Boma, Democratic Republic of Congo. It was observed that some transformers suffered two serious failures before reaching six years of use, requiring prolonged repairs, including rewinding of the windings. In addition, power outages have become common, with an average frequency of three times per week in the Boma neighborhoods, thus exacerbating the problems associated with electrical transformers. These problems are mainly attributable to fraudulent connections and subscriber departures, leading to system overload (Lierop Van & al., 2010; Thango, 2022; Elhallaoui, 2024). According to manufacturers, the typical service life of power transformers is generally between 25 and 40 years (Lierop Van & al., 2010; Thango, 2022). However, transformers in Boma City appear to experience premature failures. A similar finding has been made in other studies, where transformer performance analyses have highlighted early failures due to unfavorable operating conditions (Ghasemi & Zahediasl, 2012; Hillary et al., 2017).

The objective of this study is to analyze the voltage variations at the subscriber supply level, which affect the performance of power transformers connected to the same line of the electrical distribution network. To achieve this objective, we used R software to perform an analysis of variance (ANOVA) as well as the Tukey-Kramer test (Thango, 2022; Mampuya Nzita & al., 2024; Nzita & al., 2024). In addition, Proficad software was used to draw the electrical diagram of the studied network (Srivastava & al., 2022). A thorough field survey selected a sample of six transformers (Sekambote, Ngiengie, Kasa Vubu, Hygiene Kalamu, Kabondo 1, and Kikiaka) connected to the same power line.

Power transformers play a vital role in electricity distribution networks, reducing high voltages of transmission lines to levels more suitable for supplying subscribers (Lierop Van et al., 2010; Thango, 2022). However, their proper functioning can be compromised by various disturbances, including voltage variations (Hillary & al., 2017). Voltage variations can have several causes, such as load fluctuations, network faults, or fraudulent connections (Thango, 2022; Elhallaoui, 2024). When these variations are significant, they can lead to overvoltage or undervoltage, which are detrimental to the insulation and materials of the transformer (Hosseini & al., 2021). Many studies have analyzed the impact of voltage variations on the performance of power transformers. For example, Thango (2022) used ANOVA to diagnose transformer failures in South Africa, highlighting significant deformations of the windings. Similarly, Hillary et al. (2017) developed a tool to estimate the remaining life of transformers in Sri Lanka, based on an analysis of variance of oil parameters. In another study, Lierop & al. (2010) compared the characteristics of medium-voltage networks integrating sustainable technologies in the Netherlands, using ANOVA to identify significant differences between areas. Finally, Toubeau et al. (2014) applied ANOVA to optimize the allocation of voltage regulation devices in a distribution network in Belgium.

This work highlights the importance of a thorough analysis of voltage variations to understand their impact on the premature aging of transformers and thus contribute to improving the reliability of electrical networks. Our research hypothesis aims to determine whether voltage variations measured at twenty-nine subscriber feeders have an impact on the performance of these low-voltage power transformers. Indeed, voltage variations can cause overvoltage or undervoltage, damaging insulators and materials. Understanding and mitigating these variations is therefore essential to ensure reliable operation of large-scale electrical networks (Hosseini & al., 2021; Thango, 2022).

2. Materials and Methods

2.1. Presentation of the study environment

This study was conducted in Boma, Kongo Central Province, approximately 500 km from Kinshasa, the capital of the Democratic Republic of Congo. Boma, covering 4,332 km² and located along the Congo River (05°55' S, 12°10' E) (Wanga et al., 2015). The study began with the creation of a detailed diagram illustrating the electricity distribution network of Boma town, as shown in Figure 1. This diagram, designed using Proficad software, highlights various components of the network, including substations such as Hygiene Kalamu and Kasa Vubu, as well as transmission lines classified at 132/15 kV and 133/15 kV. In addition, it highlights the different types of cables used, including Cab MT/BT and Compact Cab MT/BT, as well as their nominal voltages. This comprehensive representation provides valuable information on the existing infrastructure and the interactions between the different elements (Srivastava & al., 2022).

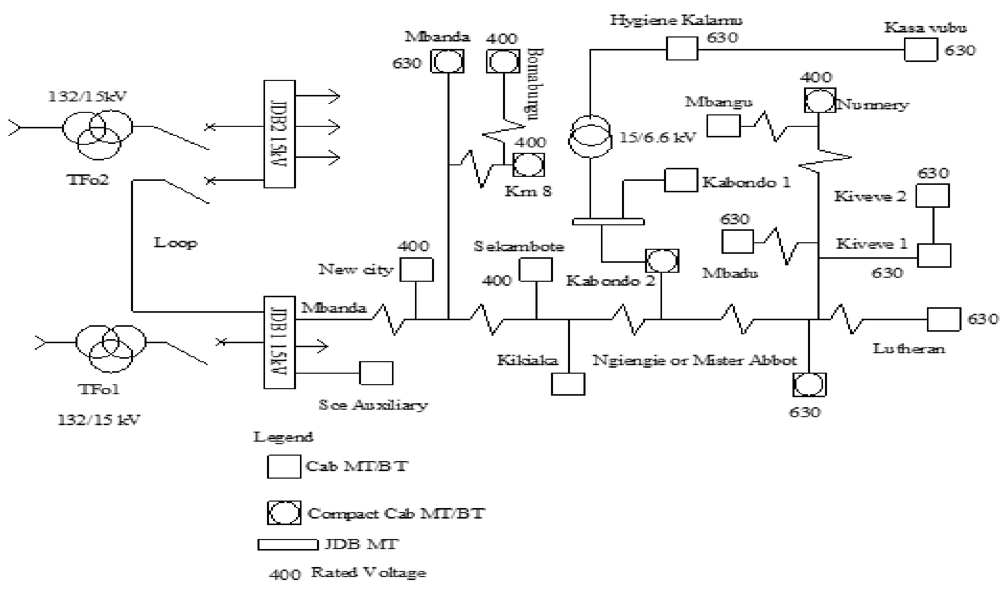

Figure 1. Electric power distribution network of the city of Boma

2.2. Data collection

For data collection, we measured the voltages at the ends of twenty-nine power lines connected to six transformers in the distribution network. This measurement process used three digital multimeters and began on April 25, 2018. The collected voltage data, detailed in table I, capture the performance of each transformer at various locations.

Table I. Voltages measured at the end of transformer lines

N°	Transformers	Starting names	Voltages at the end of the line
1	Sekambote	Phebe 1	127
2	Sekambote	Phebe 2	135
3	Sekambote	Nkondo	145
4	Sekambote	Hozo	134
5	Sekambote	Kikiaka	142
6	Mister abbot or Ngiengie	Ngiengie	171
7	Mister abbot or Ngiengie	Ntiyuma	141
8	Mister abbot or Ngiengie	Binoko	165
9	Mister abbot or Ngiengie	Zuzi	154
10	Mister abbot or Ngiengie	Nganda Tsundi	160
11	Mister abbot or Ngiengie	Madezo	161
12	Kasa vubu	Towards Commune	160
13	Kasa vubu	Towards Roundabout	178
14	Kasa vubu	Ubangi 1	149
15	Kasa vubu	Ubangi 2	152
16	Hygiene Kalamu	Webe	195
17	Hygiene Kalamu	Banana 1	167
18	Hygiene Kalamu	Banana 2	163
19	Hygiene Kalamu	Saidi	185
20	Kabondo 1	km 3	158
21	Kabondo 1	Lisala	169
22	Kabondo 1	Gen	150
23	Kabondo 1	Sekambote	169
24	Kabondo 1	Convent	144
25	Kikiaka	Career 1	156
26	Kikiaka	Career 2	164
27	Kikiaka	Church	168
28	Kikiaka	Lisala	170
29	Kikiaka	Nganda Tsundi	172

For example, the Hygiene Kalamu transformer in the Webe district recorded an unusually high voltage of 195 volts, while the Sekambote transformer in the Phebe 1 district displayed a much lower voltage of 127 volts. These discrepancies can be attributed to several factors, including varying loads on the transformers, the length of the distribution lines, and differences in the quality of the power grid in different areas (Elhallaoui, 2024; Thango, 2022).

After data collection, we compiled the voltages measured from 28 feeder lines into a comprehensive table. The results indicated a significant diversity in voltage levels, ranging from 127 volts to 195 volts. The majority of transformers showed voltages between 140 volts and 170 volts, suggesting some homogeneity within this range.

2.3. Data analysis

To further analyze the voltage variations, we created a histogram (figure 2) illustrating the distribution of the measured voltages, which highlighted that most of the values fall between 140 volts and 160 volts, while highlighting some extreme values at each end of the spectrum (Srivastava & al., 2022).

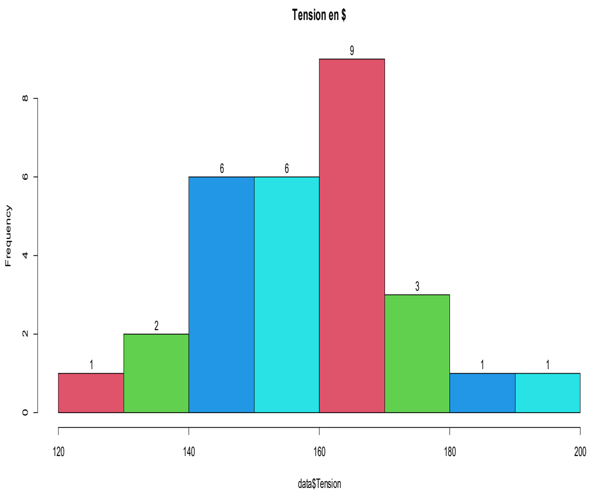

Figure 2. Histogram of transformer voltage variation

The objective of this study is not only to observe the data but also to identify areas within the power grid that may require adjustments or improvements. The ultimate goal is to harmonize voltage levels to ensure a stable and reliable power supply for the entire population of Boma (Hillary & al., 2017).

To support this in-depth analysis, we used R software to perform the statistical analysis of the collected data. This choice allowed us to perform advanced statistical tests, such as analysis of variance (ANOVA) and the Tukey-Kramer test, to identify significant differences between transformer groups. This rigorous approach enhanced the reliability and robustness of our results, allowing precise and detailed insights into the voltage variations observed in power transformers (Thango, 2022; Mampuya et al., 2024; Nzita & al., 2024).

By using this narrative methodology, we provided sufficient details regarding the analytical procedures, thus facilitating the understanding and reproducibility of our study. Our references to previous work further highlight the basis of our methodology in the existing literature (Espel, 2007; Ghasemi & Zahediasl, 2012; Toubeau & al., 2014; Elhallaoui, 2024).

3. Results

3.1. Variance analysis of transformer voltages and performance

Analysis of variance (ANOVA) revealed highly significant differences between transformer groups in terms of voltages and performances in table II. Question 1: What significant differences in voltages and performances exist between the different transformer groups according to the analysis of variance (ANOVA)?

Table II. Analysis of variance (ANOVA)

Sources of variances	Sum of squares	Degree of Freedom	Means of squares	F	P-value
Between groups	4129	5	825.8	7.34	0.000***
Within groups	2588	23	112.5		
Total	6717	28	938.3		

Analysis of variance (ANOVA) revealed highly significant differences between transformer groups in terms of voltages and performances, as shown in table II. This table presents the detailed results of the ANOVA, with the sources of variation, sum of squares, degrees of freedom, mean squares, F-test value, and associated p-value. The results indicate that the variation between groups is significant ($p < 0.001$), confirming the existence of significant differences in the characteristics of the transformers analyzed.

This in-depth statistical analysis reinforces the robustness of the conclusions drawn on the relative performances of the different transformer groups.

3.2. Visualization of voltage variations

We observed the voltage dispersions between the different groups of transformers in figure 3.

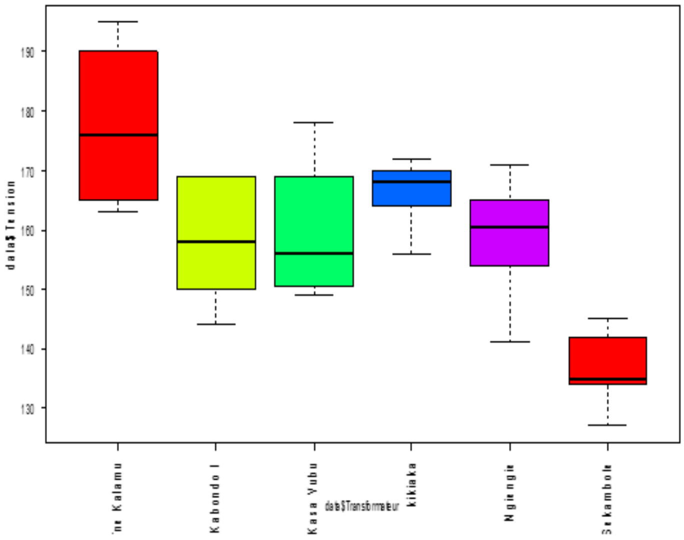

Figure 3. Boxplot of voltage variations of transformer groups.

Figure 3 shows a boxplot diagram illustrating the voltage variations observed for the different transformer groups. This graphical representation allows to visualize the dispersion of the voltage values for each group, as well as the possible differences between them. Analysis of these boxplots shows that the voltage averages for the different transformer groups are as follows: Kasa vubu at 159.75 ± 13.02 V, Hygiene Kalamu at 177.5 ± 15.09 V, Kabondo 1 at 158 ± 11.20 V, Kikiaka at 166 ± 6.32 V, Ngiengie at 158.67 ± 10.33 V, and Sekambote at 136.6 ± 7.09 V.

These results confirm the existence of significant voltage variations between the different transformer groups, with extreme values for the "Hygiene Kalamu" transformer and the "Sekambote" transformer. This graphical representation thus allows us to better understand the extent of the voltage differences observed on the Boma city's electrical network.

3.3. Tukey's multiple comparisons of performance differences between pairs of transformers

Tukey's multiple comparisons test (Tukey Riley HSD) showed highly significant differences between certain pairs of transformers in table III. Question 2: What significant differences were identified between pairs of transformers using Tukey's multiple comparisons test ?

Tableau III. Turkey test on the of power transformers

Hygiene Kalamu - Kasa vubu	17.15	-5.53	41.026	0.209
Kabondo 1-Kasa vubu	-1.75	-23.83	20.33	0.999
Kikiaka - Kasa vubu	6.25	-15.83	28.33	0.948
Ngiengie - Kasa vubu	-1.08	-22.33	20.16	0.999
Sekambote - Kasa vubu	-23.15	-45.23	-1.068	0.03*
Kabondo 1-Hygiene Kalamu	-19.5	-41.582	2.581	0.105
Kikiaka-Hygiene Kalamu	-11.5	-33,582	10,582	0.597
Ngiengie-Hygene Kalamu	-18.83	-40.081	2.415	0.103
Sekambote-Hygiene Kalamu	-40.9	-62.982	-18.818	0.0000983***
Kikiaka-Kabondo 1	8.00	-12.82	28.82	0.836
Ngiengie-Kikiaka	0.667	-19.27	20,599	0.999
Sekambote-Kabondo 1	-21.4	-42.22	-0.581	0.042*
Ngiengie-Kikiaka	-7.33	-27.27	12,599	0.859
Sekambote-Kikiaka	-29.4	-50.22	-8.581	0.003**
Sekambote-Ngiengie	-22.1	-41.99	-2.13	0.024*

Tukey's multiple comparisons test (Tukey HSD) revealed highly significant differences between some pairs of transformers, as shown in table III. This table presents the detailed results of the test, including mean differences, confidence intervals, and associated p-values for each pair of transformers. The results show that some comparisons, such as that between transformer "Sekambote" and "Hygiene Kalamu," display an extremely low p-value (0.0000983***), indicating a very significant difference between these two groups. Other comparisons, such as that between "Sekambote-Kabondo 1," "Sekambote" and "Kasa vubu," as well as "Sekambote" and "Kikiaka," and "Sekambote-Ngiengie," also show significant differences with respective p-values of 0.042*, 0.03*, 0.003**, and 0.024*.

However, it is noteworthy that ten pairs did not show statistical significance, which highlights the importance of identifying transformer groups that actually show notable differences in performance. These results allow a better understanding of voltage variations between transformers and can guide decisions regarding the optimization of their operation in the power grid.

4. Discussion

4.1 Variance analysis of transformer voltages and performance

Our analysis of variance (ANOVA) results highlights significant differences between transformer groups in terms of voltages and performance, with a sum of squares between groups reaching 4129, suggesting that some transformers operate less efficiently than others. This may have direct impacts on the reliability and quality of service of the power grid. Subsequent studies corroborate these results. For example, Thango (2022) showed that ANOVA is effective in diagnosing transformer failures, revealing significant deformations in the windings. Hillary (2017) also demonstrated the usefulness of ANOVA in estimating the residual life of transformers by analyzing oil parameters, while Toubeau. (2014) identified significant differences in the performance of medium voltage networks using this same statistical approach. To conclude, a hypothesis test could be relevant to examine whether voltage variations systematically lead to transformer failures. This would help guide maintenance and optimization strategies. Future recommendations include automating ANOVA analysis and exploring the effects of voltage variations on long-term performance, thereby helping to anticipate outages and improve network management (Toubeau, 2014; Thango, 2022; Hillary, 2017).

4.2 Visualization of voltage variations

The box plot presents the voltage variations for the different transformer groups, indicating a significant dispersion in voltage values. This graphical representation highlights the potential differences between the groups, which is crucial for the evaluation of the power system performance (Nzita et al., 2024). The analysis of the voltage averages shows that "Hygiene Kalamu" has the highest value at 177.5 ± 15.09 V, while "Sekambote" displays the lowest at 136.6 ± 7.09 V. These results confirm the existence of significant variations between the groups, which is corroborated by previous studies that highlight the importance of voltage monitoring to avoid malfunctions in power systems (Hillary et al., 2017).

The extreme variations observed for the "Hygiene Kalamu" and "Sekambote" transformers raise concerns about the stability and reliability of the power system. Previous research has shown that such fluctuations can lead to equipment damage and service interruptions (Fu et al., 2020). These findings highlight the importance of proactive voltage management in the Boma power system, with implications for the development of maintenance and control strategies. Similar studies have recommended interventions to stabilize voltages and prevent outages (Thango, 2022). The results of this voltage analysis highlight the need for rigorous monitoring and effective management of transformers. A hypothesis test could be conducted to determine whether the observed differences between transformer groups are statistically significant, thereby validating maintenance and voltage management strategies.

4.3 Tukey's multiple comparisons of performance differences between pairs of transformers

Further analysis using post hoc tests revealed specific differences between several transformer pairs, highlighting the increased sensitivity of Sekambote transformers to voltage fluctuations compared to other groups such as Hygiene Kalamu, Ngiengie, Kasa Vubu, and Kikiaka. This increased sensitivity highlights the fact that some transformers are more vulnerable to voltage fluctuations, increasing the risk of failure and operational problems. Subsequent studies confirm these findings. For example, Thango's. (2022) study demonstrated that certain transformer models exhibit greater resilience to voltage fluctuations, reinforcing the notion that certain designs are optimized for stability. Similarly, Hillary. (2017) showed that robust transformer design can reduce the risks associated with voltage fluctuations, while Toubeau. (2014) observed similar performance between different transformer types under varying voltage conditions. In conclusion, a hypothesis test may be necessary to assess whether the sensitivity of Sekambote transformers to voltage fluctuations is significantly different from that of other groups.

This could guide management and maintenance decisions in the context of power grid planning. The results suggest that certain transformer models, capable of withstanding fluctuations, could offer a strategic advantage in managing the stability and reliability of the power grid.

5. Conclusion and recommendations

This study highlights the significant impact of voltage variations on the performance of electrical transformers in the city of Boma. The results of the variance analysis revealed significant differences between transformer groups, thus highlighting the importance of rigorous voltage management to prevent outages and optimize the reliability of the electrical network. It was observed that some installations, such as the "Sekambote" transformer, are particularly vulnerable to voltage fluctuations, which can lead to harmful overloads or undervoltage. Recommendations

include the installation of real-time monitoring systems to quickly detect voltage variations and the adaptation of transformer designs to local specificities. In addition, the implementation of preventive maintenance protocols and the training of technical staff are essential to ensure the durability and performance of the equipment. Finally, this research paves the way for future studies on the impact of voltage variations on other transformer parameters, thus contributing to the optimization of power distribution systems.

Acknowledgment

We would like to thank the National Electricity Company of Boma for its valuable support in carrying out this study.

Funding

There was no funding for this article.

Conflict of Interest statements

The authors declare no conflict of interest in the publication process of the research article.

Ethical Considerations

This article was prepared in accordance with ethical research principles, ensuring compliance with current standards. It is important to note that no human or animal data were used in this study, ensuring full compliance with ethical requirements. The authors also declare that they have no conflicts of interest regarding this research, which reinforces the study's credibility. The data used for this analysis were obtained ethically and legally, complying with all relevant regulations. Finally, the study results were presented honestly and transparently, without any data manipulation, to ensure the scientific integrity of the entire work.

Authors contributions

In the research article, each author played a vital role in developing and finalizing the manuscript.

A.M.N: was responsible for writing and preparing the original version, as well as analyzing and validating the final version.

A.-P. K.T: focused on collecting the data needed for the study. Meanwhile,

L.M.M.: was responsible for revising the survey to ensure its relevance and clarity.

P.B.M.: participated in revising the original version to improve its quality.

G.W.N.: made additional revisions to refine the content.

G.D.N.: oversaw the entire process, ensuring that all steps were followed correctly. Finally,

C.N.U.-D.-M.: performed the final revision, ensuring that the article was ready for publication. All authors have read and approved the final version of the manuscript.

ORCID of the Authors

Mampuya N.A.: https://orcid.org/0009-0007-6092-145X

N'zau C.: https://orcid.org/0009-0007-3515-1588

Kumbu T.A-P: https://orcid.org/0009-0005-1771-1436

Mwanda M.L.: https://orcid.org/0009-0008-6181-5648

Biabia M. P.: https://orcid.org/0009-00005-2243-5923

Wanlogo N.G.: https://orcid.org/0009-0008-8359-5893

Dituba N.G. : https://orcid.org/0000-0002-9671-3819

Références

Chen, J. M., Yao, C. Y., Sheu, S. P., Chiou, Y. C., & Shih, H. C. (1997). The study of carbon half-cell voltage in lithium-ion secondary batteries. *Journal of Power Sources, 68, 242-244.* https://doi.org/10.1016/S0378-7753(97)02650-5

Elhallaoui, Y. (2024). Automating software regression testing through log analysis: A statistical comparison approach using NLP techniques and hypothesis. Science Top: *Computer Science and Engineering, 1-58.* https://doi.org/10.13140/RG.2.217846.31042/1

Espel, P. (2007). Development of a digital sampling wattmeter. *Review French of Methodology, 4, 1-12.*

Fu, W., Jin, L., Ling, M., Zheng, Y., & Shi, L. (2020). VASTA: Un outil d'analyse statistique de synchronisation à tension large basé sur des modèles de retard de cellule sensibles à la variation. *IEEE Access, 8, 197194-197202.* https://doi.org/10.1109/ACCESS.2020.3035263

Ghasemi, A., & Zahediasl, S. (2012). Normality tests for statistical analysis: A guide for non-statisticians. *International Journal of Endocrinology and Metabolism, 10(2), 486-489.* https://doi.org/10.5812/ijem.3505

Hillary, W. D. A., Jayrathna, L. T., Ranasighe, S. M. B. P., Samarakoon, N. M. T. N. R., & Lucao, J. R. (2017). A tool for estimating remaining lifetime of a power transformer. *Martuwa Engineering Research Conference, 1-7.* https://doi.org/10.1109/IMERcon.2017.798513

Hosseini, S., Deng, X., Miyake, Y., & Nozawa, T. (2021). L'encouragement de la prise de parole par la rétroaction en temps réel a un impact sur la génération d'idées créatives dans les dyades. *IEEE Access, 9, 57976-57988.* https://doi.org/10.1109/ACCESS.2021.3072790

Lierop Van, J. H. M., Veldman, E., Vanalme, G. M. A., & Kling, W. L. (2010). Evaluating the power capability of a Dutch MV grid incorporating sustainable technologies. In Proceedings of the 45th International Universities Power Engineering Conference (UPEC 2010). *Cardiff, Wales, 1-5.*

Mampuya Nzita, A., Phuku Phuati, E., Muanda Ngimbi, R., Dituba Ngoma, G., & Masiala Mavungu, N. (2024). Etude des vibrations latérales dans l'unité turbine-alternateur 5 de la centrale hydroélectrique d'Inga 2. *IgMin Res, 2(4), 255*-260. https://doi.org/10.61927/igmin173

Nzita, A.M. (2024). Analyse statistique du vieillissement des composants électriques dans le groupe 6 de la centrale hydroélectrique d'Inga 2 suite à des arrêts brusques. Recherche Computationnelle et Expérimentale sur les Matériaux et les Énergies Renouvelables, 7(2), 78-92. https://doi.org/10.19184/cerimre.v7i2.51268

Srivastava, H., Kaushal, A., Kumar, H., & Tripathi, A. (2022). A design and development of baggage sorting systems at the airport. *Evergreen Joint Journal of Novel Carbon Resource Sciences and Green Asia Strategy, 9, 86-92.* https://doi.org/10.5109/4774219

Thango, B. A. (2022). Application of the analysis of variance (ANOVA) in the interpretation of power transformer must. *Energies, 15, 7224-7232.* https://doi.org/10.3390/fr15197224

Toubeau, J. F., Lobry, J., Vallée, F., & DeGrève, Z. (2014). Optimal allocation process of voltage control devices and operational management of the voltage in distribution systems using the experimental design method. *In IEEE International Energy Conference (Energycon), Dubrovnik, Croatia, 1141-1149.* https://doi.org/10.1109/ENERGYCON.2014.6850559

Wanga, B.M., Wafula, M.D., Mafuana, L.C., and Z. Victorine Mbandu, Z.V. (2015). Kalamu River in the town of Boma in the DRC: a disappearing tourist site. *International Journal of Innovation and Applied Studies, 11(1), 118-128.*