

---

# An Investigation into Electrical Distribution Losses on Zesco Network: A Case Study of Chipulukusu Compound, Ndola

Francis Kafata<sup>1\*</sup>, Davies Nyauti<sup>2</sup>, Francis Manunga<sup>3</sup> and Derick Chileshe<sup>4</sup>

<sup>1,2,3,4</sup>School of Engineering, Dept. of Electrical/Electronics, Zambia University College of Technology, Ndola, Zambia.

\*Corresponding author email id: [fkafata@zut.edu.zm](mailto:fkafata@zut.edu.zm)

Date of publication (dd/mm/yyyy): 30/04/2026

---

**Abstract** – Electrical distribution losses remain a critical challenge in power networks, especially in densely populated areas with aging or substandard infrastructure. This study investigates the nature and extent of distribution losses in the ZESCO network, focusing on Chipulukusu Compound in Ndola. The aim of this study was to evaluate impact of distribution power losses on energy delivery and proposing appropriate mitigation strategies. A survey design which used both quantitative and qualitative aspects of research was used in the study. Data collection methods included meter readings, thermographic scanning, transformer and line inspection sheets, as well as questionnaires and interviews administered to both ZESCO staff and clients. The study population comprised 7,595 customers: 7,142 residential, 63 social (e.g., schools, hospitals), and 390 commercial clients. The sample consisted of 1,500 residential clients, 30 social clients, 150 commercial clients, and 15 Zesco staff members from operations, maintenance, protection, and commercial departments. Additionally, 23 out of 33 distribution transformers in the area were inspected. Data were analyzed using the STATA statistical software. The findings revealed that unbalanced transformer loading accounted for 91% of technical losses, leading to transformer overheating, insulation failure, and phase-specific outages-particularly affecting customers connected to the yellow and blue phases. Copper conductor theft contributed to 65% of non-technical losses, while 50% of residential clients were vending electricity worth ZMK 100 or less per month, largely due to frequent outages, compared to those vending between ZMK 100 and ZMK 500 who had more stable supply. Additional non-technical loss factors included the misuse of residential power for commercial purposes and illegal connections, particularly in market areas. The study recommends that ZESCO adopt regular transformer load balancing and preventive maintenance to minimize technical failures. Furthermore, community awareness campaigns should be intensified to reduce theft and discourage unauthorized commercial use in residential areas. The government is also urged to implement regulatory mechanisms for the disposal and trade of scrap metal to curb the illicit sale of stolen copper conductors.

**Keywords** – Electrical Distribution Losses, ZESCO Network, Technical Losses, Non-Technical Losses.

---

## I. INTRODUCTION

Electrical energy is a form of energy that is generated through different source, one of the common sources being hydro power generation, while others form include photovoltaic energy source, wind energy source, nuclear energy source, thermal energy source and many more others. This energy is transported from the generating plants to the consumers or load through electrical network composed of transmission lines (conductors), transformers, distribution lines (conductor) or cables and other switch gears [1]. Due to these transmission and distribution media, losses can be generated. Efficiency of electrical energy distribution is very important for the sustainable functioning of any power network. Distribution losses refers to the difference between the energy entering the distribution network and that leaving it. The losses in power distribution systems can be classified as technical and non-technical losses. Technical losses are easily determined by looking at the relationship between voltage and current on a distribution network. According to the Zesco

---

Integrated Reports [1, 2, 3], distribution losses have been increasing from 11% to 14.8% in the years 2019-2020 and on several occasions failing to meet its 10% loss standard. Technical losses can be defined as the losses associated to losses of electrical energy due to conductor heating ( $I^2R$ ), heat dissipated in transformers (iron losses), faults such as symmetrical and unsymmetrical, electrical discharge due to corona effect (ionization of the air surrounding a conductor), load imbalances, heat dissipated in motors [4, 5, 6]. While non-technical power losses can be those energy losses associated to unbilled energy consumed, this can be meter bypass, errors in meter reading, corrupt meter readers who manipulate the readings for their own benefit for consumers who are not on prepaid, vandalism that leads to loss of power to consumers [1].

## II. RELATED WORKS

In [7] the research noted that as the power distribution network increases in size the complex is to determine and solve the challenges of power losses. It further identified that one of the major causes of these power losses in three phase four network is current imbalances. While the research observed this challenge it also emphasized low-cost measures such as phase balancing during operation and routine maintenance has the potential to reduce the losses, thereby improving power system efficiency, increases network handling capacity, and reduces operational costs. In [8] the noted that the location as well as the capacity of the power plant in power distribution system has an impact on the power losses. The research proposed advanced power flow algorithm to determine line losses and an improved gray wolf optimization algorithm to establish the optimal location and rating of distributed generators. An experiment was conducted on IEEE 33-bus radial distribution network to examine the effectiveness of the proposed method and it was concluded the system significantly reduced the active power losses in the distribution system. In [9] presented the challenges the India's power distribution system was facing in its quest to provide power to the consumers. It observed that the most notable ones were the Aggregate Technical and Commercial power losses which greatly affected the financial standing of distribution utility companies and therefore increased electricity tariffs for consumers. The research focused on improving the power network efficiency and strengthening revenue standing of the utility companies by reviewing technological advancements that can be used to reduce Aggregate Technical and Commercial power losses and it discussed the practical shortcomings encountered during the implementation process.

In [10] observed that with high penetration of distributed generation (DG) it calls for effective evaluation of its distribution network loss uncertainty in voltage and current delivery. The research proposed a nodal loss analysis technique which recursively calculates power losses due to the connected loads and penetration of distributed generation. In [11], and Lubov Petrichenko, observed that the integration of large scale photovoltaic (PV) energy system introduces power losses. The research did a comparison on two case scenarios one for prosumers operating individually and the other one prosumers participating in PV energy communities. They observed that from the simulation performed on IEEE 123 Node Test Feeder it was clear that power losses can only decrease to a certain level with PV penetration and beyond that limit (point), increase in PV capacity also increases losses rapidly and system stability becomes complicated making system operation difficult. In [12] the research carried a review on the global perspective on non-technical power losses focusing on unbilled consumed electrical energy and its implication based on economic, social impact. It further looked at key barriers to their identification and also evaluated the main strategies, policies, and regulatory frameworks practiced in many countries for mitigation of power losses.

In [13] the research evaluated the technical and non-technical power losses in the 20/0.4 kV power distribution network of Sheberghan City, Afghanistan. A mixed-methods design was used for data collection combining field measurements, utility records, and personal interviews with technical staff. It was established that the major source of technical losses was due to conductor resistance, transformer overloading, and aging power infrastructure, while non-technical losses was as a result of billing errors, illegal connections, and operational inefficiencies on the power network. In [14] the research observed that non-technical losses were preventable due to the nature of their source which is electricity theft and fraud as compared to technical losses which are inherent and are dependent power network design. Hence in their study the focus was on non-technical power losses where perspectives, existing detecting techniques and mitigating strategies for their reduction were discussed. In [15] the research reviewed the nexus among electricity distribution power losses, focusing on carbon emissions, economic growth, and energy consumption in West Africa for the period ranging from 1970 to 2019. The study observed that empirical evidence revealed a statistically significant negative relationship between electricity distribution power losses and energy consumption. In [16] the study evaluated the methods for distribution power losses calculations. The research focused on the losses related to the load and based its analysis on the operational methods, analytical methods and evaluation methods. In [17] noted that one of the major challenges in power distribution is electricity theft which is contributing to power losses and negatively affected the economic standing of the utility companies. The study further evaluated the role the smart meters in mitigating electricity theft and compared to traditional analogue meters that are dependent on human intervention in meter reading. They research concluded that from the results obtain in the Akre district power distribution network in Iraq proved that smart meters were able reduced electricity theft by 96.4% while power losses reduced by 17.1%. This led to improved power supply, system stability and economical standing of the electrical utility companies.

In [18] the study noted that non-technical power losses such as illegal meter taping were responsible for financial losses in most utility companies. The research analysed different machine learning methods that are used for the determination of non-technical losses. In [19], the research noted the implementation and growth of smart grids has benefited the community with reliable power supply. However, this has come with challenges of non-technical losses which has seen utility companies failing to meet their operation costs. The notable ones include meter tempering, meter bypassing and lack of meter capability to process huge data, and increasing operational costs due the network complexity. In [20], the observed that the technical losses are those that give rise to heat dissipation in electrical elements such as transformers, conductors, motors and switch gears. The study noted that reduction of these power losses require integrated efforts as their source is based on electrical design. In summary we look at the Zambian scenario in respect to technical and non-technical losses. From IEC (2009) defines the optimal average range of technical power losses in transmission and distribution power network under normal operation conditions as being [21]:

1. 1% to 2% for a step-up generator-transformer.
2. 2% to 4% for transmission lines, depending on the length of a line.
3. 1% to 2% for a step-down transformer connecting a distribution system to a transmission system.
4. 4% to 6% for a distribution network transformer and lines, combined.

While the Word Bank (2009) defines the most optimal range of power system losses from transmission to dis-

-tribution power network under normal operation conditions falls within 7% to 10% [21]. ZESCO accumulated an equivalent of 108MW distribution power losses on average per annum and an equivalent of 111MW transmission power losses on average per annum from the years 2020 to 2022. Hence it can be approximated that 219MW of the power transmitted and distributed by ZESCO per annum was power losses. From an audit of ZESCO’s self-reported key performance indicators (KPI) on distribution system power losses given in table 1 below indicates that within the period 2020 to 2022, the utility purchased an average power of 7,473.64GWh per annum where 952.76GWh (or an equivalent of 108.67MW) were reported to power losses, giving a percentage value of 12.75%. Which is higher than 11% regulatory KPI target by 1.75% [21].

Table 1. ZESCO’s 3-year distribution system losses performance against KPI target and benchmark [21].

ZESCO Distribution System	Quantity in Year				
	2020	2021	2022	3-Year Avg.	3-Year Total
Energy purchased (GWh)	6,535.97	7,718.52	8,166.41	7,473.63	22,420.90
Energy purchased – average power (MW)	0.74	0.88	0.93	0.85	2.56
Reported energy losses (GWh)	939.55	847.25	1,071.48	952.76	2,858.29
Energy losses – average power (MW)	106.96	96.72	122.32	108.67	326.29
Reported energy losses	14.38%	10.98%	13.12%	12.75%	12.75%
Regulatory target for losses	11%	11%	11%	11%	11%
World Bank benchmark for losses	10%	10%	10%	10%	10%
Losses in excess of KPI target (GWh)	220.60	(1.79)	173.18	130.66	391.99
Losses in excess of WB benchmark (GWh)	285.96	75.40	254,843.14	205.40	616.20

From the reviewed literature it is clear that technical power losses and non-technical power losses require integrated approach if they are to be reduced to the acceptable limit. Their impact on the power network has serious setback to both the utility companies and consumers. With the rapid increase in human population and increased industrial activities calls for efficient and stable power supply to the end users.

### III. RESEARCH METHODOLOGY

The research divided the distribution power losses into two categories: Non-Technical Power Losses (NPTL) and Technical Power Losses (TPL). In this research both cross-sectional survey design implementing qualitative method on a smaller scale and quantitative survey method on a larger scale to obtain evidence. Each level of the survey method was carefully designed in line with the single line diagram of Chipulukusu network to maximized data collection, analysis and evaluation.

#### A. The Sampling Design and Sample Size

##### a. The Research Population

The study population comprised residential consumers, social consumers (e.g., schools, hospitals), commercial consumers and Zesco members of staff under operations, maintenance, protection, and commercial departments, as well as distribution transformers under Chipulukusu network.

### b. *Sample Population*

The study population comprised 7,595 consumers: 7,142 residential consumers, 63 social consumers (e.g., schools, hospitals), and 390 commercial consumers. The sample consisted of 1,500 residential consumers, 30 social consumers, 150 commercial consumers, and 15 Zesco staff members from operations, maintenance, protection, and commercial departments. Additionally, 23 out of 33 distribution transformers in the area were inspected.

### c. *Sample Strategies*

This research adopted probability sampling known as Simple Random Sampling (SRS), such that the selection of respondents and transformers was purely based on chance and no involvement of individual bias [21]. This sampling technique allows every element involved in the sampling frame to have an equal chance of being selected and be part of the sample.

### B. *Data Collection*

The secondary data for this research was acquired by using sources such as; the public documents, which included ERB reports, Zesco integrated reports, journal papers and past researches and this data has been used in the related works section. While primary data was collected from the field through reading the installed bulk meter at the main substation, by the use of Thermal graphic cameras, using data capturing instruments and survey questionnaires.

### C. *Data Analysis*

Qualitative data that was acquired through questionnaires, interviews and review of public documents and past research was analyzed, later arranged in themes. On the other hand, quantitative data was analyzed through the application of statistical software known as STATA and with tools such as pie charts, frequency tables, and bar charts adopted for presentation [22].

## IV. POWER DISTRIBUTION SYSTEM

The study was carried out in the city of Ndola of the Copperbelt province of Zambia focusing on 66/11kV Depot substation supplying Chipulukusu compound. The single line diagram of 66/11kV Depot substation in Ndola is given in Fig. 1 below.

### A. *Technical Losses*

The technical losses on the power distribution network can be classified as those caused by faults such as symmetrical or balanced faults, unsymmetrical or unbalanced faults, open circuit losses, transformer loading, power losses associated to conductor resistance ( $I^2R$ ), Transformers core losses (eddy current and hysteresis), poor power factor losses.

#### i. *Important Equations/Formulae*

$$\text{Conductor power losses} = P_{loss} = (I^2R)\text{watts} \quad (1)$$

$$\text{Hystereses power losses} = P_h = \eta B_{max}^n fV \text{ watts} \quad (2)$$

$$\text{Eddy current losses} = P_{eddy} = V \cdot (B_{max} \cdot f \cdot t)^2 \text{ watts} \quad (3)$$

$$\text{Power factor} = \cos\theta = \frac{P}{VI} \quad (4)$$

With reference to Fig. 2 below power losses can be calculated as given below:

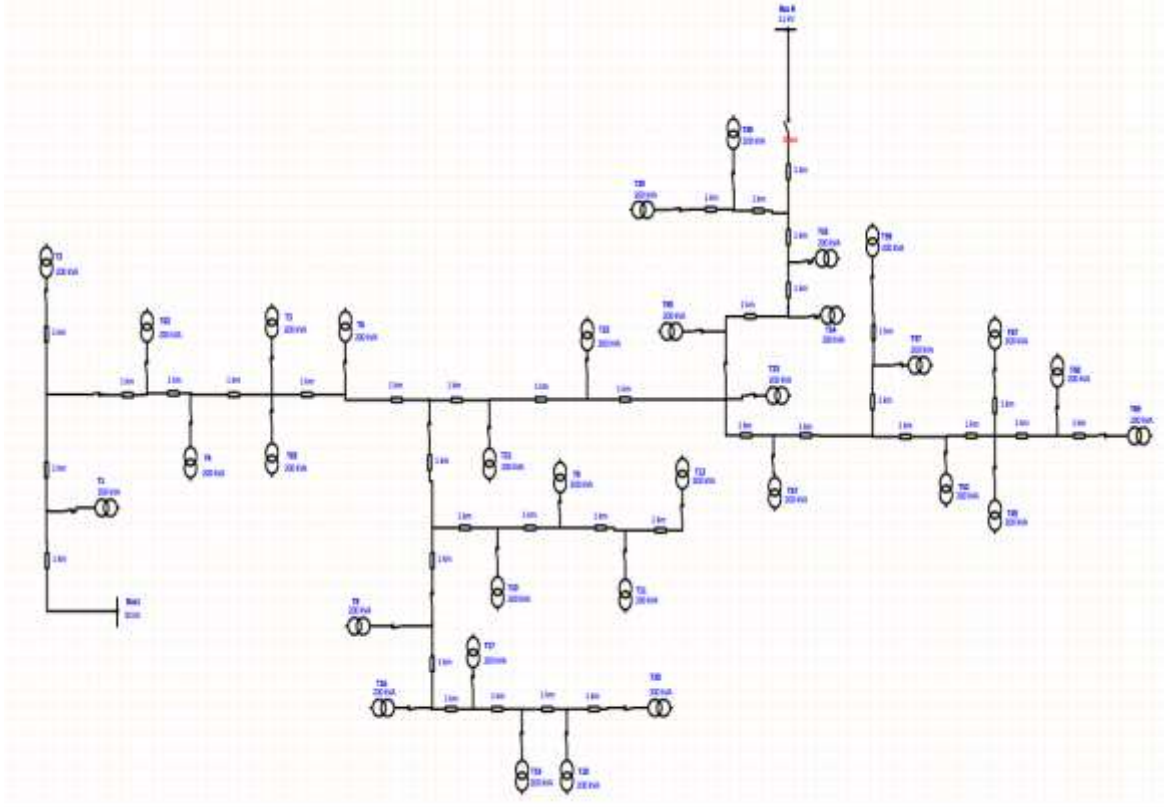


Fig. 1. Feeder 2 Single line diagram from Depot substation feeding Chipulukusu Compound, Ndola, Zambia (source: field data 2024).

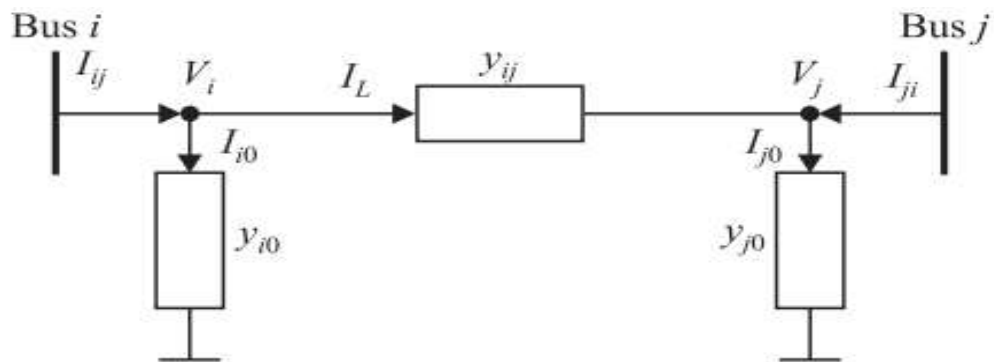


Fig. 2. Two bus power network.

Considering current and power flows for the two buses (*i to j*) is given by:

Case 1 from bus (*i to bus j*)

$$I_{ij} = I_L + I_{i0} = y_{ij}(V_i - V_j) + y_{i0}V_i$$

$$S_{ij} = V_i I_{ij}^* = V_i^2 (y_{ij} + y_{i0})^* - V_i y_{ij}^* V_j^* \quad (5)$$

Case 2 from bus (*j to bus i*)

$$I_{ji} = -I_L + I_{j0} = y_{ij}(V_j - V_i) + y_{j0}V_j$$

$$S_{ji} = V_j I_{ij}^* = V_j^2 (y_{ij} + y_{j0})^* - V_j y_{ij}^* V_i^* \quad (6)$$

There power loss between the two buses is given by:

$$S_{Loss} = S_{ij} + S_{ji} \quad (7)$$

The unbalanced faults allow the follow of negative and zero sequence voltages and currents depending on the nature of a fault, while positive sequence are the normal.

The matrix that governs the relationship between the sequence currents and line currents is given in equation 8 below.

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (8)$$

Case 3 single line to ground fault (in phase a) and the conditions at the fault point are expressed below.

$$I_b = I_c = 0 \quad (9)$$

$$I_a^f = I_a \quad (10)$$

Hence the positive ( $I_{a1}$ ), negative ( $I_{a2}$ ) and zero ( $I_{a0}$ ) sequence currents are given by:

$$I_{a1} = I_{a2} = I_{a0} = \frac{1}{3} I_a \quad (11)$$

$$I_{a1} = I_{a2} = I_{a0} = \frac{E_a}{(Z_1 + Z_2 + Z_0) + 3Z_f} \quad (12)$$

Case 4 double line to ground fault (in phases b and c and ground), and the conditions at the fault point are expressed below:

$$V_b = V_c = Z^f (I_b + I_c) \quad (13)$$

$$I^f = I_b + I_c \quad (14)$$

$$I_a = 0 \quad (15)$$

Hence the positive ( $I_{a1}$ ), negative ( $I_{a2}$ ) and zero ( $I_{a0}$ ) sequence currents are given by:

$$I_{a0} = \frac{-E_a + Z_1 I_{a1}}{Z_0 + 3Z_f} \quad (16)$$

$$I_{a2} = \frac{-E_a + Z_1 I_{a1}}{Z_2} \quad (17)$$

$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_2(Z_0 + 3Z_f)}{Z_2 + Z_0 + 3Z_f}} \quad (18)$$

Case 5 double line (between phases b and c) and the condition at the fault point are expressed below:

$$I_b = -I_c \quad (19)$$

$$I_a = 0 \quad (20)$$

Hence the positive ( $I_1$ ) and negative ( $I_2$ ) sequence currents are given by:

$$I_{a0} = 0 \tag{21}$$

$$I_{a1} = \frac{1}{3}[a - a^2]I_b \tag{22}$$

$$I_{a2} = \frac{1}{3}[a^2 - a]I_c \tag{23}$$

While fault currents are given by:

$$I^f = I_b = -I_c = I_{a1}(-j\sqrt{3})\frac{E_a}{(Z_1+Z_2+Z^f)} \tag{24}$$

### B. Non-Technical Losses

Non-Technical losses on the power distribution network can be classified as those due to meter bypass, error in meter reading, fault meters, meter tampering, unpaid bills, frauds by billing staff, system software errors. Fig. 3 below gives the structure of the power distribution losses.

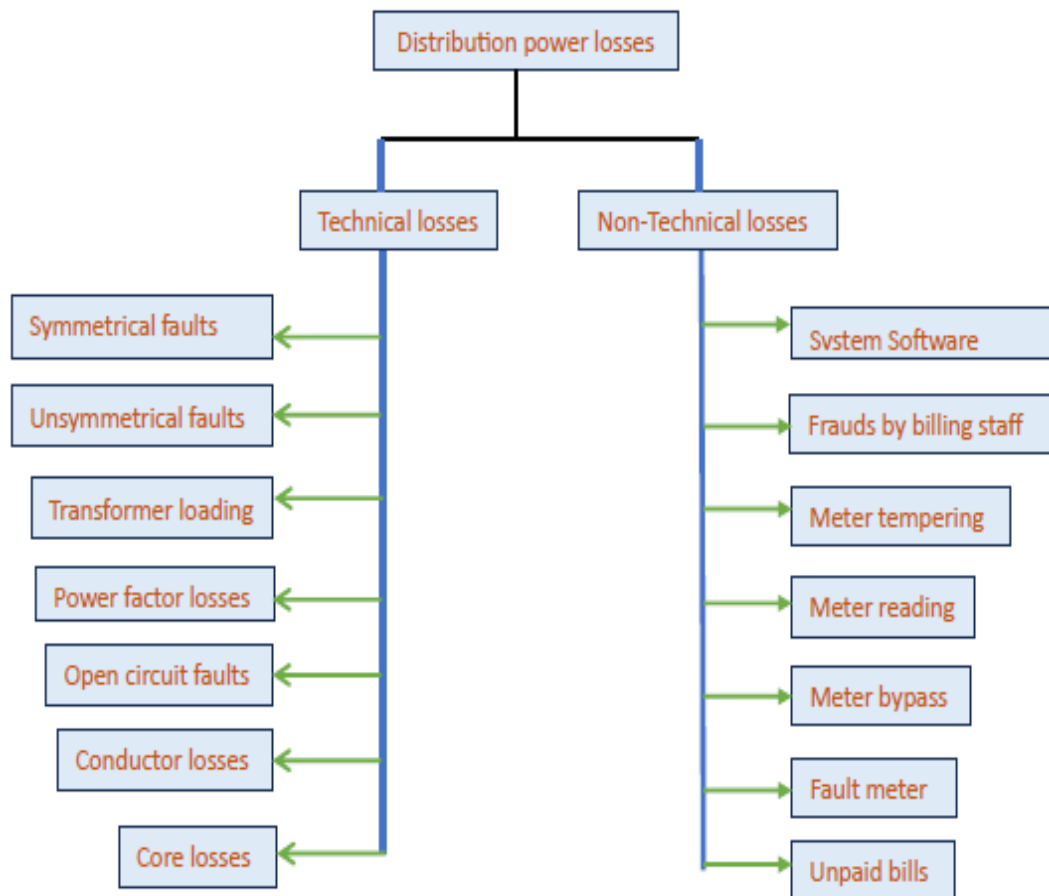


Fig. 3. Distribution power losses taxonomy.

A three-phase meter shown in Fig. 4 was installed at 66/11kV Depot substation supplying Chipulukusu compound to capture power readings. The network under study had a total number of thirty-three (33) distribution transformers supplying seven thousand five hundred and ninety-five 7595 consumers, categorized into residential, social and commercial consumers. The majority of the distribution transformers under this network are pole mounted with the ratings ranging from 100 KVA to 200 KVA.



Fig. 4. Three phase meter at 66/11kV Depot substation (source: field data 2024).

## V. RESULTS PRESENTATION AND DISCUSSION

This section presents the results obtained in the field and responses that have been analyzed using graphs, tables and charts.

### A. Power Readings

The meter readings were obtained for a period of ten (10) months from January 2024 to October 2024 focusing of KWh and KVA readings. Fig. 5 shows the graphical KWh meter readings which reflect the cumulative energy consumption on Feeder 2 at the beginning of each month which showed steady increase from month to month, signifying a consistent rise in energy usage within Chipulukusu network. The upward trend in kWh readings implies that the Chipulukusu community's overall electricity needs growing. The meter served as a baseline for understanding overall energy flow within the network. While Fig. 6 shows the graphical KVA meter readings. Unlike the steady increase observed in kWh, the kVA readings fluctuated month by month, reflecting variability in peak power demand. These demand spikes highlight the importance of load management and may indicate times when the feeder is under more stress. This information is essential for optimizing the feeder's performance and minimizing potential distribution power losses.

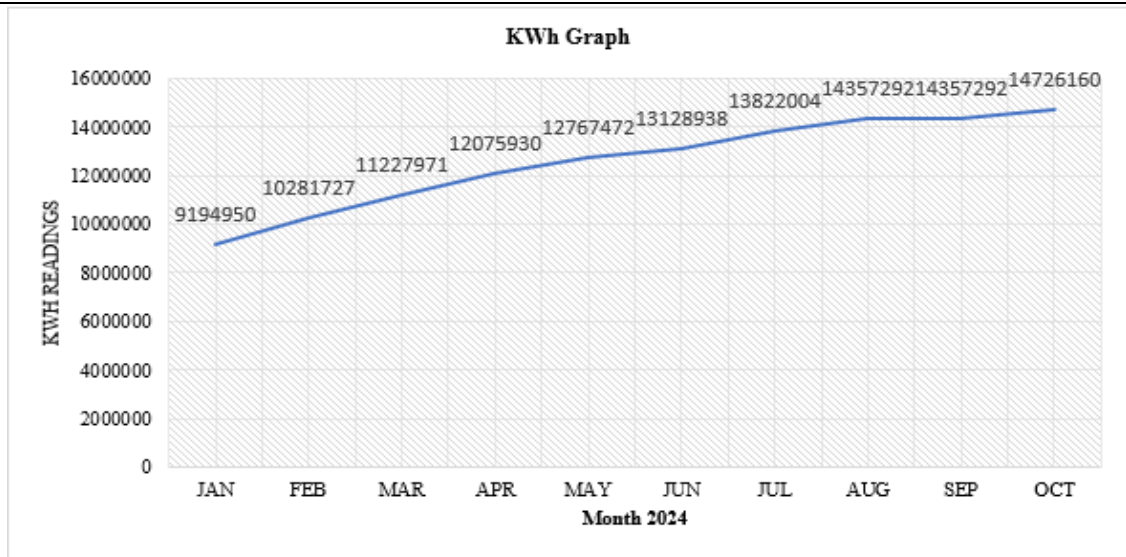


Fig. 5. KWh Graphical meter readings (source; field data 2024).

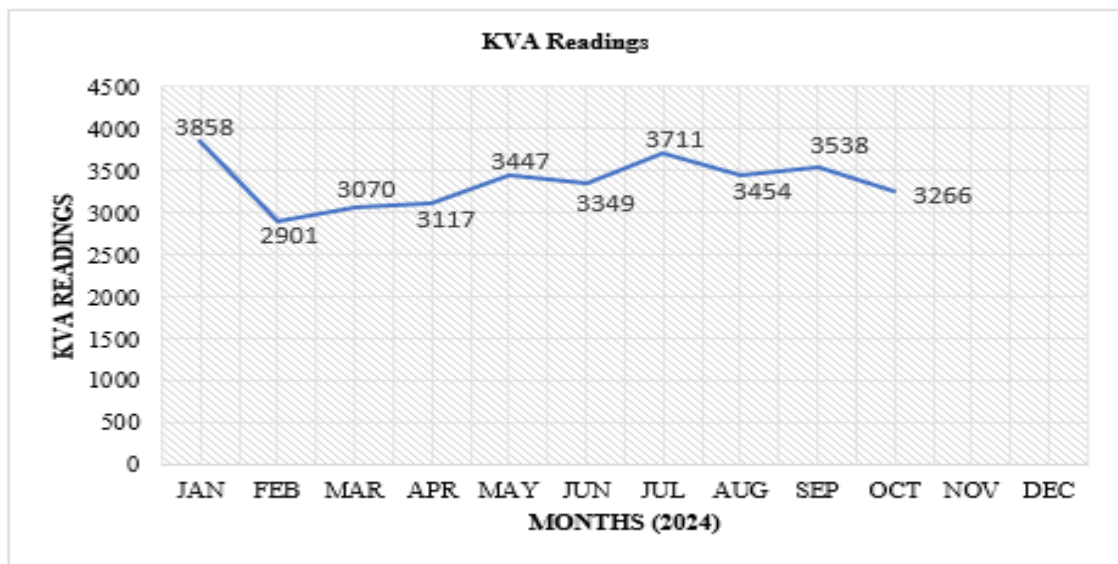


Fig. 6. KVA Graph (source; field data 2024).

### B. Transformer Loading

Readings of phase currents and voltage was taken for the sampled transformer to determine their loading. Table 2 shows the phase current and voltage readings with a focus of determining the balancing status of each transformer. From table 2 it can be observed that out of 23 sampled transformers only two were balanced and 21 were unbalanced or not balanced which means that they allowed the flow of positive, negative and zero sequences. Due to unbalanced conditions of these transformers resulted into transformers losses, and since the phases supplying the consumers were also not balanced it presented the presence of variables losses.

Table 2. Transformer (Tx) loading (source: field data 2024).

Tx ID	Rating (kVA)	Currents (A)				Voltages (V)	Time	Load
		R	Y	B	N			Balancing
A	200	14.5	41.3	79.3	33.2	240	12:26	unbalanced

Tx ID	Rating (kVA)	Currents (A)				Voltages (V)	Time	Load
		R	Y	B	N			Balancing
B	200	15.2	43.5	77.7	67.5	237	12:40	unbalanced
C	100	5	32.5	26.1	33	238	12:53	unbalanced
D	200	2.1	2.3	1.9	0.6	240	13:10	balanced
E	200	14.4	28.3	50	35.1	239	13:23	unbalanced
F	100	2.4	22.7	19.7	19.4	238	13:41	unbalanced
G	200	8.2	8.9	40.5	31.5	238	13:56	unbalanced
H	200	34.9	37.2	66.2	22.2	240	14:20	unbalanced
I	200	5.2	5	6	0.5	241	14:39	balanced
J	200	13.4	19.9	19.4	20.2	237	14:52	unbalanced
K	200	10.7	20.8	22.4	11.6	240	07:10	unbalanced
L	200	8.9	19.9	25	20	239	07:23	unbalanced
M	200	45.4	9.3	15.2	11.4	239	07:41	unbalanced
N	200	57.4	82.1	114.8	38.9	237	08:02	unbalanced
O	200	17.8	24	20.5	13.1	240	08:15	unbalanced
P	200	24.5	29.6	7	21.3	240	08:31	unbalanced
Q	200	8.7	26.9	40.3	34	240	09:15	unbalanced
R	200	2.8	29	31.5	25	239	13:25	unbalanced
S	200	19.8	7.4	9.4	9.7	237	13:41	unbalanced
T	200	17.4	14.2	20.4	9.7	240	13:53	unbalanced
U	200	6.4	16.1	8.3	10.2	238	14:12	unbalanced
V	200	19.4	8	21.6	14.5	241	14:30	unbalanced
X	200	13.5	21.3	17.1	16.6	240	14:47	unbalanced

*C. Views Held by the Utility Staff on the Major Causes of Distributions Losses*

The members of staff interviewed attributed that the major challenges to some of these losses were as a result of meter tempering by consumers more especially those mounted in houses, power cable theft and transformer vandalism leading to prolonged repair time, while some attributed it to consumers performing commercial activities such as wilding in their residences against the declared loads of domestic consumption, this led to imbalances in line currents and frequent conductor failures. However, others attributed the power losses due to unplanned settlement making certain distribution lines covering longer distances, posing maintenance challenges and delayed fault responses due difficult in accessibility.

*D. Rate of Response to Faults*

The responses from the sampled consumers over the general rate of response to faults (on a general perspective without specifying the nature of the fault) by the utility company is given in Fig. 7 from which we can see that 40% responded that it was very fast within a maximum of 10 hours after the fault is reported. Those that responded that it was fast within 24 hours of the fault being reported represented a percentage of 25% while those that responded that it was slow beyond a day represented a percentage of 35%. From the responses it can be concluded that on average consumers could go for a day without power when a fault occurs. This represents a significant loss of revenue to the utility company more especially if the fault is affecting a large number of consumers such as a fault on a transformer, since this Chipulukusu compound is one of the densely populated areas.

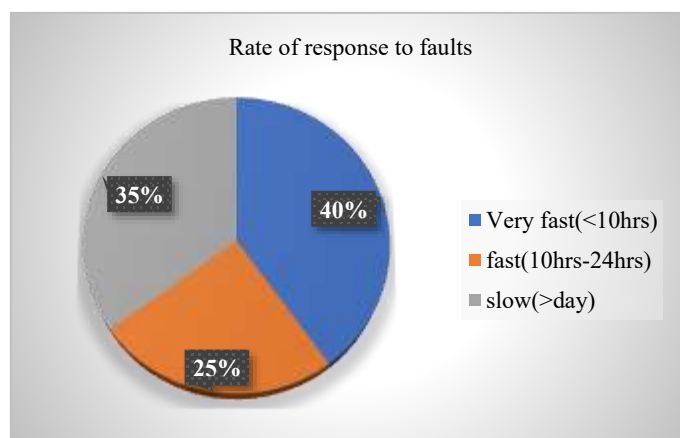


Fig. 7. Rate of Response to faults (source: field data 2024).

## VI. CONCLUSION

This research has provided some insights to the taxonomy of the distribution power losses in the area under study. This study revealed the presence of both technical and non-technical distribution power losses was notable through factors such as transformer loading imbalances and the slow response to fault resolution, allowing consumers to go for a day or days without power. Future research should focus on strengthening fault resolution strategies to reduce consumer lost hours and transformer optimization aiming at load balancing. Also fault reporting channels and meter monitoring techniques.

## REFERENCES

- [1] Vunda Ngulumingi Christian, Meni Babakidi Narcisse and Lidinga Mobonda Flory, (2023), "Analysis of Energy Loss in an Electrical Energy Distribution Network". American Journal of Engineering Research (AJER). Volume-12, Issue-3, pp-35-42.
- [2] Zesco limited, (2019) "Annual integrated report". <https://41.222.16.129/investment/annual-reports>.
- [3] Zesco limited, (2020) "Annual integrated report". <https://41.222.16.129/investment/annual-reports>.
- [4] Dasman Dasman. (2018) "Analysis of power loss of 20 kV power distribution". MATEC Web of Conferences 215, 01040 Doi.org/10.1051/mateconf/201821501040.
- [5] Emir Alibašić, Zoran Baus, and Maja Muftić-Dedović, (2021) "Estimation of electricity losses in distributed electricity network using an improved three mode method. B&H Electrical Engineering, Volume 15.
- [6] Integrated Resource Plan for the Power Sector in Zambia. (2023) Summary Report.
- [7] Emad Hussen Sadiq, Rakan Khalil Antar, and Safer Taib Ahmed (2022) "Power losses evaluation in low voltage distribution network: a case study of 250 kVA, 11/0.416 kV substation". Indonesian Journal of Electrical Engineering and Computer Science, Vol. 25, Issue No. 1, pp. 35-41.
- [8] P. Li, H. Dong, G. Zhang et al. (2023) "Research on loss reduction strategy of distribution network based on distributed generation site selection and capacity". Energy Reports, volume 9, PP: 1001-1012.
- [9] B. Durga Naik, and M. Chinnalal (2020) "Study on aggregate technical & commercial losses in power distribution system. Journal of Emerging Technologies and Innovative Research (JETIR), Volume 7, Issue 2.
- [10] Hongmei Li, Hantao Cui, and Chunjie Li, (2019) "Distribution Network Power Loss Analysis Considering Uncertainties in Distributed Generations. Sustainability, Volume 11, 1311; doi:10.3390/su11051311.
- [11] Illia Diahovchenko, and Lubov Petrichenko, (2023) "Assessment of energy losses in power distribution systems with individual pro-

- mers and energy communities”. The Journal of Engineering. DOI: 10.1049/tje2.12243.
- [12] Fernando de Souza Savian , Julio Cezar Mairesse Siluk, Taís Bisognin Garlet, Felipe Moraes do Nascimento, Jose Renes Pinheiro, and Zita Vale (2021) “Non-technical losses: A systematic contemporary article review. Renewable and Sustainable Energy Reviews, Volume 147, 111205. Doi.org/10.1016/j.rser.2021.111205.
- [13] Tordimurad Chenag, Uloghbek Talaash and Zabihullah Baluch (2025) “Analysis of Technical Electrical Issues and Energy Losses in a 20/0.4 kV Power Distribution Network: A Case Study of Sheberghan City. International Journal of Current Science Research and Review., Vol 8, Issue No 8. DOI: 10.47191/ijcsrr/V8-i8-33
- [14] Bruno Knevizt Hammerschmitt, Alzenira da Rosa Abaide, Felipe Cirolini Lucchese, Alexandre Schopf da Silveira, Criciele Castro Martins, Alexandre Schopf da Silveira, Jonas Rigodanzo, Joao Vitor Maccari Brabo Castro and Julio Affonso Dall Agnol Rohr. (2020) “Non-Technical Losses Review and Possible Methodology Solutions”. 6th International Conference on Electric Power and Energy Conversion Systems (EPECS. DOI: 10.1109/EPECS48981.2020.9304525.
- [15] Atiku, et al.: (2022) “The Effect of Electricity Distribution Loss, Electricity Power Consumption, Electricity Intensity on Energy Consumption in West Africa. International Journal of Energy Economics and Policy” Volume 12, Issue no. 5, PP: 361-369. DOI: <https://doi.org/10.32479/ijeep.13386>.
- [16] Abat Muratov, Zliza Saparniyazova, Bakhadirov, and Alibiy Bijanov. (2021) “Analysis of electricity loss calculation methods in distribution networks”. E3S Web of Conferences 289, 07017. Doi.org/10.1051/e3sconf/202128907017
- [17] N.J. Faqishafyee, E.H. Sadiq, and H.M. Taha, (2024) “Mitigating non-technical losses and electricity theft through smart meters: A case study of the Akre district power distribution network,” Journal of Intelligent Systems and Control, Vol. 3, Issue no. 3, pp. 135-151. <https://doi.org/10.56578/jisc030301>.
- [18] Safdar Ali Abro et al. (2025) “Non-technical loss detection in power distribution networks using machine learning”. Scientific Reports” 15:36189. <https://doi.org/10.1038/s41598-025-20048-z>
- [19] Xudong He, Jian Wang, Jiqiang Liu, Enze Yuan, Kailun Wang, and Zhen Han. (2021) “Smart Grid Non-Technical Loss Detection Based on Power Gateway Consortium Blockchain”. Security and Communication Networks. Doi.org/10.1155/2021/9501572.
- [20] Parvizi, P.; Jalilian, M.; Amidi, A. M.; Zangeneh, M. R. and Riba, J.-R. (2025) “Technical Losses in Power Networks: Mechanisms, Mitigation Strategies, and Future Directions”. MDPI (Electronics), Volume 14, 3442. <https://doi.org/10.3390/electronics14173442>.
- [21] Sharma, C.H., Srivastava, U.K., & Shenoy, G.V. (1983) “Quantitative Techniques for Managerial Decisions”, New Delhi: New Age International (P) Limited.
- [22] Miles, M.B., & Huberman, A.M. (1994) “Qualitative Data Analysis: An Expanded Sourcebook”. Thousand Oaks, CA: Sage Publications.

## AUTHOR’S PROFILE



### First Author

**Francis Kafata**, received his bachelor’s degree in Electrical and Electronics Engineering from the Copperbelt University, Kitwe, Zambia in 2012; He received his master’s degree in Electrical and Electronics Engineering from the Copperbelt University in 2019 and obtained a Masters in Education from Information and Communication University, South Korea in 2016. He is currently pursuing his PhD degree in Electrical and Electronics Engineering from the Copperbelt University, focusing on grid integration of renewable energy using model predictive control method. He has 20 years of industrial experience and 6 years of teaching experience. His research interests include protection engineering, power systems analysis and industrial instrumentation.



### Second Author

**Davis Nyauti**, received his bachelor’s degree in Electrical and Electronics Engineering from the University of Zambia in 2024. He is currently working as a principal engineer for Zesco. **email id:** [Dnyauti@zesco.co.zm](mailto:Dnyauti@zesco.co.zm)



### Third Author

**Francis Manunga**, received his bachelor’s degree in Electrical and Electronics Engineering from the University of Zambia in 2024. He is currently working as a graduate engineer for Zesco. **email id:** [FManunga@zesco.co.zm](mailto:FManunga@zesco.co.zm)



### Fourth Author

**Derick Chileshe**, received his bachelor’s degree in Electrical and Electronics Engineering from the University of Zambia in 2024. He is currently working as a graduate engineer for Elsewedy electric Zambia. **email id:** [derickchileshejr@gmail.com](mailto:derickchileshejr@gmail.com)