FAULT ANALYSIS AND CIRCUIT BREAKERS SELECTION FOR ELECTRICAL LINES PROTECTION: CASE OF ELECTRICAL LINE FROM LUTCHURUKURU TO KINDU (D.R. CONGO)

M N Audry [1], H Shabani [1,2], J Fisher [2] and J Ngondo [1,3]

[1] Electrical Engineering, MAPON University, Kindu-Maniema, Democratic Republic of Congo (D.R. Congo)
[2] School of Electrical and Communications Engineering, Papua New Guinea University of Technology (Unitech), Lae 411, Morobe Province, Papua New Guinea
[3] North China Electric Power University, 02, Beinong Lu, Changping, Beijing, China

ABSTRACT

Consumption of electrical energy has steadily increased due to industrial, commercial and demographic growth. In order to deliver constant power to consumers, reliability is an important factor that power companies must take into account. Common disturbances on transmission lines resulting from various faults such as line to line, single line to earth, double line to earth and faults between three lines affect the stability of the electric supply. This paper seeks to demonstrate the behavior of transmission line signals due to disturbances caused by different types of faults and to identify the effect of faults on transmission lines as well as on the bus assembly. Simscape Power tool available in MATLAB/Simulink environment was used to model the 33 kV, 105 km transmission line. Its simulation made it possible to obtain the voltage and the current wave forms in the transmission network during the occurrence of different fault types. The electrical faults cause down time equipment damage and, thus, present a high risk to the integrity of the power grid. After various fault analysis of the power line from Lutchurukuru to Kindu, the circuit breakers to be placed at the transmitting and receiving ends of this power line were selected with the aim of reinforcing the power line protection system. Hence, the circuit breakers at the transmitting end (Bus 2) of the line must have a breaking capacity of 4.376 MA, a voltage of 34.5 kV, a number of cycles for the fault interruption time of 5 and a sub transient fault current of 49.15 A, while the ones placed at the receiving end (Bus 7) of the line must have a breaking capacity of 497.5 kA, a voltage of 34.5 kV, 5 number of cycles for fault interruption and a sub transient fault current of 5.6 A.

KEYWORDS

Transmission lines, reliability, faults, Circuit breaker, MATLAB/Simulink

1. INTRODUCTION

For the transmission and distribution of electrical energy, the lines are the vital links to ensure the continuity of services to users, the latter are exposed to atmospheric and natural conditions which increase the probability of appearance of any type of faults [1]. Faults in power lines occur in unusual conditions due to climate (Lightning, strong Wind, tremors, weight of ice on conductors, trees, contaminated or broken insulators, corona not controlled, aircraft and cars hitting lines and structures) [2] and human errors. The analysis of faults forms an important step on the study of electrical system; the problem consists of determining the bus voltages

DOI : 10.5121/ijcsea.2025.15502

and the line current during the appearance of different types of faults. Faults on electrical equipment are subdivided into two categories including balanced three phase faults and unbalanced faults (single phase fault, two phase fault, fault between two phases and earth) [3]. The information obtained after fault analysis is necessary for the parametrization and coordination to obtain the nominal values of the protective equipment [4].

However, the electrical line from Lutchurukuru to Kindu requires reinforcement in its protection system, along this line it is found certain protective devices such as fuse holder disconnectors (already defective and replaced by bare wires in the open air), Lightning arrestors, but there are no circuit breakers at both ends of this line or a relay for faults detection and isolation of defective areas. Maniema is supplied with electricity by the Lutchurukuru power station via a 105 km power line [5]. This paper analysesvarious faults that may appear in this line during operation which will make it possible to make a good choice of protection devices and to configure the monitoring device to thus, protect this line and to guarantee residents of the town of Kindu with continuous and reliable power supply. The main goal is to present the behaviour of bus voltage and line currents during normal and faulty operating conditions. The following steps were undertaken before circuit breaker selection to ensure the protection of the Lutchurukuru Kindu line by:

- Modelling of Lutchurukuru-Kindu Power Network;
- Simulating the network, under normal conditions;
- Simulating various types of faults in the power line;
- Selecting appropriate circuit breakers for the power line protection.

The above simulations were carried out on the Simulink environment.

2. FAULTS IN POWER SYSTEMS

In general, the balanced systems only exist in theory, in reality many systems are almost unbalanced and for practical reasons they can be analysed as balanced. However, there are emergency conditions (open conductors, unbalanced loads…) where the degree of unbalance can no longer be neglected. To protect the system against such eventualities, it is necessary to size protection devices such as fuses, circuit breakers and to adjust protection relays [6]. To do this the voltage and currents in the system during unbalanced faults must be known in advance. Faults in electrical lines can be classified into two type, series faults (open conductors) and shunt faults (short circuit). Series faults are easily identified by observing the value of each phase voltage [7]. If the fault voltage value is zero it indicates that fault has occurred, in case current value increases it means a shunt fault has occurred. Short circuit faults may be asymmetrical (line to ground, line-to-line, double line to ground) or symmetrical (triple line and triple line to ground) [1], [8]. On Fig. 1 we observe the classification of faults in overhead transmission lines where A, B, C and G indicate respectively the three phases and the ground.

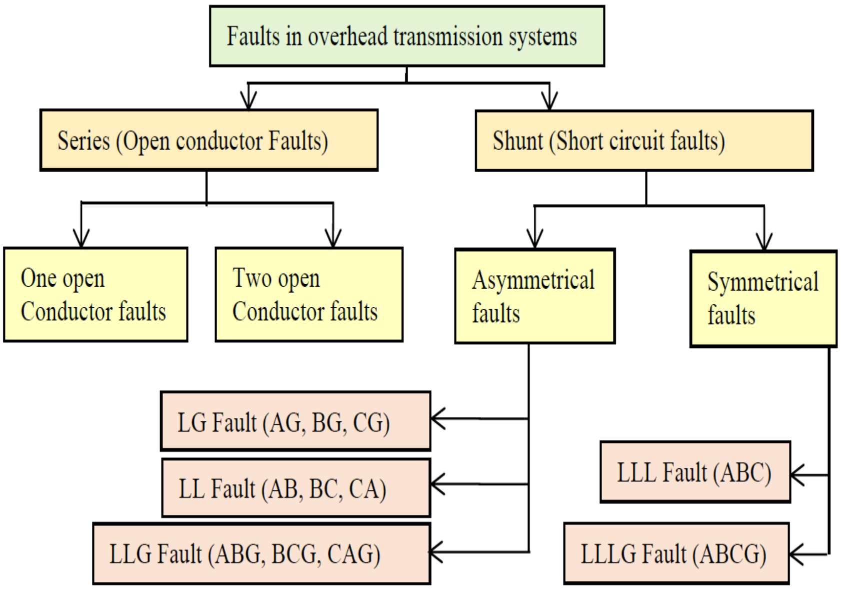


Figure 1. Faults classification [7].

2.1. Fault Effects

Heavy short circuit may cause damage to equipment or any other element of the power system due to overheating or flashover, different phenomenon may be observed [9], [10];

- There may be reduction in the supply voltage of the healthy feeders, resulting in the loss of industrial loads.
- Short circuit may cause the unbalance of the supply voltages and currents, thereby heating rotating machines.
- There may be a loss of the power stability
- The faults may cause an interruption of the supply to consumers;

Thoughtful result of the uncleared faults, is fire which may not destroy only the equipment of its origin but also may spread within the system and cause total failure.

2.2. Faults types in Transmission Lines

Normally a power system operates under balanced conditions. When the system is unbalanced due to the insulation failures at any point or due to the contact of live wires, a short circuit or fault is said to occur [1]. Faults that occur in transmission lines are classified into two groups as:

- Symmetrical faults
- Asymmetrical faults.

1. *Symmetrical faults.*It is a fault which appears when all three phase conductors are short circuited, the latter gives balanced faults currents. Three phase to ground fault is shown in the following Fig. 2.

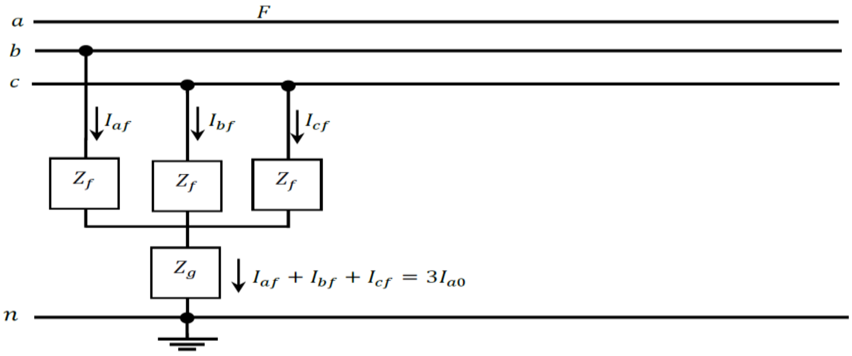


Figure 2. Symmetrical faults.

For this type of fault, it should be noted that:

- Symmetrical faults rarely appear in practice since the majority of faults are non-symmetrical.
- The symmetrical fault is the most dangerous since it imposes a large fault current on the circuit breakers.

1. Asymmetrical faults.These faults lead to unequal currents with unequal phase shifts in a three-phase system. This may occur by natural disturbances or by human errors with open conductors or short circuit [11]. As presented in the Fig. 3, asymmetrical faults are generally classified as:

- Single line to ground fault (L – G fault)
- Double line fault (L – L fault)
- Double line to ground fault (L – L – G fault)

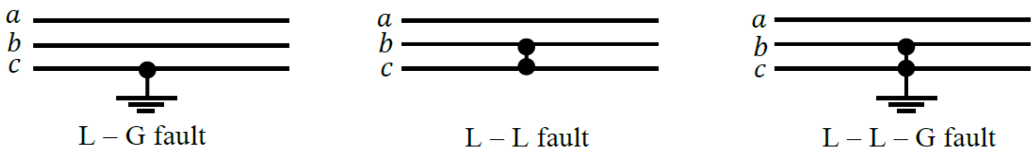


Figure 3. Asymmetrical faults.

The single line to ground (L – G fault) is the most current fault (60 to 75% of occurrence). They appear when a conductor of transmission line falls to earth or during contact between the latter and the neutral conductor [1]. A fault between two phases appears in an electrical line when two conductors are short circuited (L – L fault). The occurrence frequency rate of this fault type fluctuates between 5 to 15%. The fault between two phases and earth in transmission line appears when two conductors fall and are connected together across the neutral (L – L – G fault). The occurrence frequency rate of this fault type fluctuates between 15 to 25% [12]. A fault study comprises the following [3]:

- Determination of the maximum and minimum three phase short-circuit currents;
- Determination of asymmetrical fault currents;
- Rating evaluation of required circuit breakers;
- Investigation of schemes of protective relaying;
- Determination of voltage levels at strategic points during faults.

3. TRANSMISSION LINE PROTECTIVE DEVICES

Transmission system must be protected from short circuit currents, which can endanger personnel and cause permanent damages to critical equipment [13]. To guarantee a safely isolation of the system faulty parts, the fault current must not exceed the capacity of the circuit capacity device [14]. Various types of protection devices in transmission systems as shown in Fig. 4.

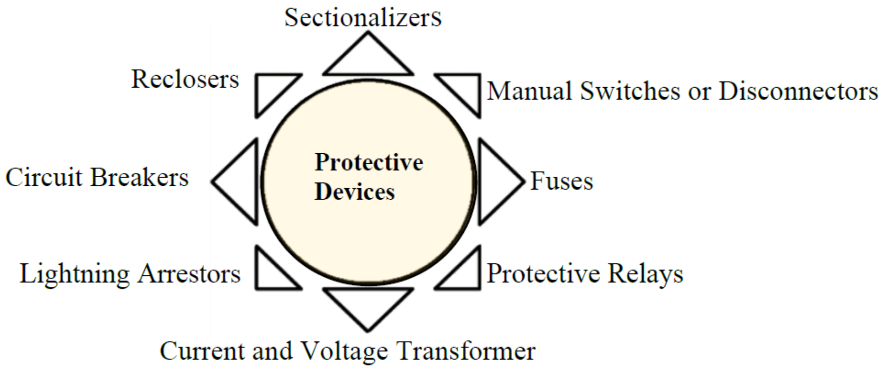


Figure 4. Various protective devices.

The purpose of protective device is to detect abnormal signals in the power transmission system [2]. A protection system consists of a set of devices intended for fault and abnormal situation detection in networks in order to control the triggering of cutting elements. The functional chain of a protection system includes one part for fault detection and another part for fault elimination [12], [15]. As presented in Fig. 5, whatsoever the technology, the protection system is made up of the following three fundamental parts [16]:

- Sensors or measuring reducers which lower the values to be monitored (current, voltage) to levels usable by the protection;
- Protective relays;
- Switching equipment (one or more circuit breakers).

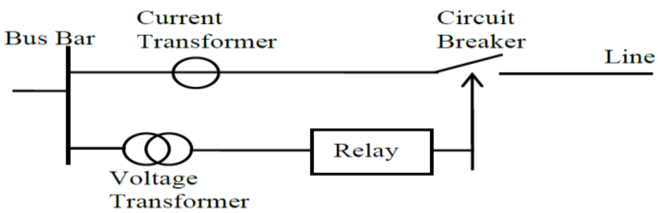


Figure 5. Fundamental elements of protective systems.

At the receiving end of the line there is a similar protection system, in the event of a fault the circuit breaker opens and the line is taken out of service [16].

3.1. Fault Location

Different techniques and methods have been introduced on fault location estimation; among them impedance-based faults location methods are the most used by utilities [17]. Based on the input data (voltage and current) of fault location algorithm, the algorithms can be categorized as:

- One end algorithm method which is economic and simple but subjected to different errors such as the uncertainty of transmission lines, unbalanced load flow, the accuracy of transmission line model [18], and measurement errors. With this method the location of fault is based on the impedance from one end of a transmission line [19].
- Two end algorithm method which estimates the location of fault using voltage and current from both ends of a transmission line [20].

3.2. Circuit Breaker Selection

When a fault appears the protection devices are activated (relay and circuit breaker). A short time called tripping time elapsing before the protection relay detects the overcurrent and launches the tripping pulse to the circuit breaker [21]. For the circuit breaker to open, another time called opening time passes. The circuit breaker opening is accompanied with an arc which is extinguished after a duration called arc time. The time from which the tripping pulse is launched until the arc is extinguishing is called interruption time. The speed of the circuit breaker will therefore be recognized according to the time which elapses between the appearance of the fault and extinction of the arc [22]. The selection of circuit breakers is based on the following factors [1]:

- Class of the voltage considered (nominal effective voltage level);
- The load current that the circuit breaker must withstand in the normal or emergency condition;
- The short circuit current that the circuit breaker must withstand;
- The speed of interruption of the short circuit (the latter depends on the number of interruption cycles and the network frequency.

The load current in normal operation can be found by studying the power flow of the circuit to be protected [23]. The short circuit data determines the selection of the circuit breaker by taking into account the operating voltage [24]. In general, the quicker the circuit breaker interrupts a fault, the better it is for the system because there is a reduction in the risk of damage devices [25], [26].

4. DESCRIPTION OF LUTCHURUKURU – KINDU NETWORK

TheFig. 6 illustrates the single power line diagram of Lutchurukuru to Kindu network. The Lutchurukuru power plant is designed with 3 turbo alternator groups of 2700 kVA each, but currently only one remains working with a power production of around 500 kW. The output voltage is 6.6 kV. The transformer station is located at the outlet of the power plant where two 2 MVA transformers are placed in parallel which raise the voltage up to 33 kV for its transport to the town of Kindu located approximately at 105 km where the overhead line stays on pillars of 10 m in height. It is a three-phase line with one terminal, its phase conductors have a diameter of 50 mm.

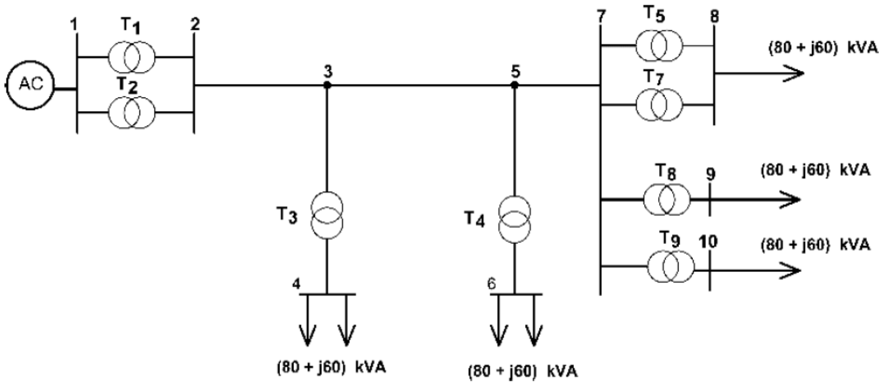


Figure 6. Single power line diagram: Lutchurukuru to Kindu network

5. ELECTRICAL NETWORK DESIGN SIMULATION MODEL

The Lutchurukuru – Kindu electrical network was modelled and simulated in the MATLAB/Simulink platform as shown in the figure 7.

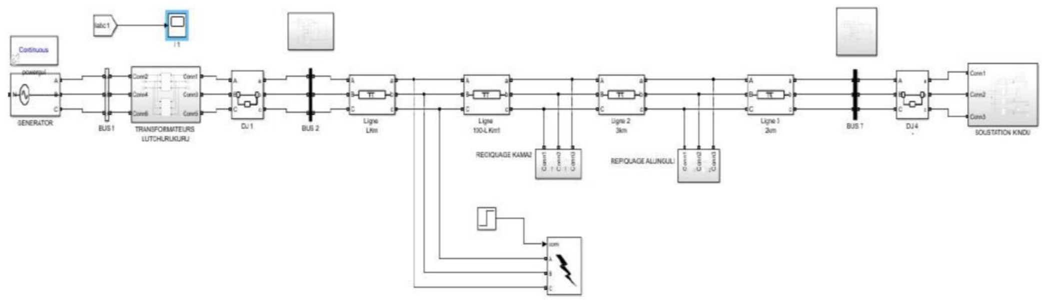


Figure 7. Single power line diagram: Lutchurukuru to Kindu network

The generator produces a voltage of 6.6 kV that is raised to 33 kV at the level of power point (Lutchurukuru power plant) then transported at a distance of 105 km. Along the power line two transplants are made simultaneously over 100 and 103 km at different nodes as given in table 1.

Table 1. Load power at different nodes.

Location	Node	P (kW)	Q (kVAR)
Alunguli	4	80	60
Kama 2	6	80	60
Kindu	8	80	52.5
Kindu	9	100	75
Kindu	10	120	90

The power line will be protected by two circuit breakers, one at the transmitting end of the line (Bus 2 at Lutchurukuru) and the other at the other at the receiving end (Bus 7 at Kindu), it has been split into two parts (with a total length of 100 km) to allow faults to be simulated at different positions along the line using fault simulator block. The electrical power is generated by a three-phase power source, which is transmitted to the various loads thought transmission lines, whose parameters are shown in the table 2.

Table 2. Transmission line parameters of the πmodel

Specifications	Values	Unit
Length	100, 2 et 3	km
Positive Sequence Resistance	0.512	Ω/km
Homopolar Resistance	0.371	Ω/km
Positive Sequence Inductance	2.29	mH/km
Homopolar Inductance	10.154	mH/km
Positive Sequence Capacitance	4.4	nF/km
Homopolar Capacitance	9.56	nF/km

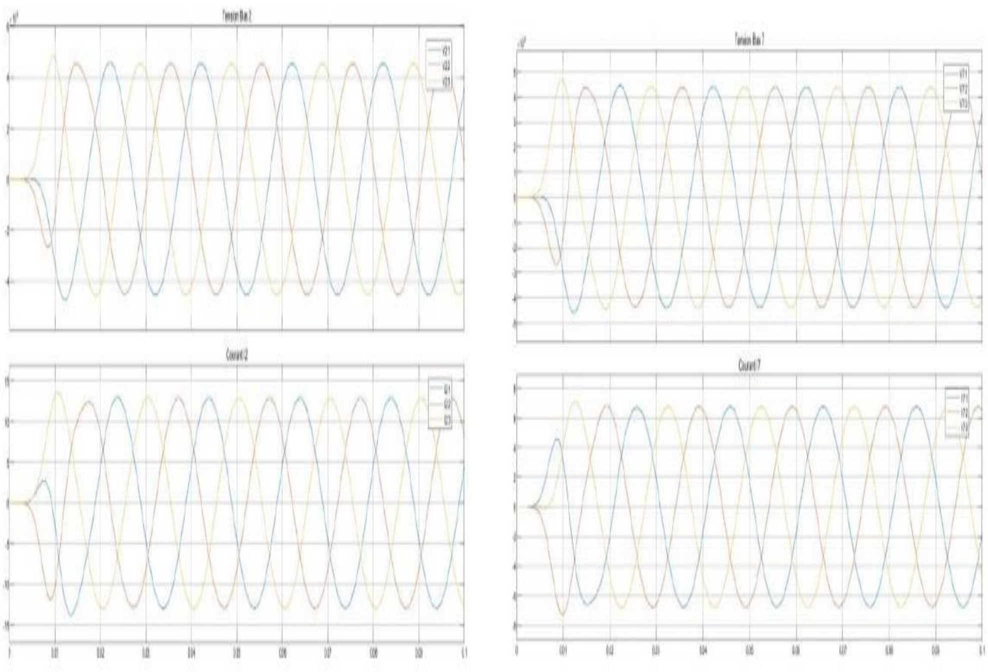
6. SIMULATION RESULTS AND CIRCUIT BREAKER SELECTION

For the analysis and evaluation of Lutchurukuru-Kindu power line network, the following faults were simulated:

- Three phase faults;
- Single line to ground faults;
- Fault between two phases: without earth and with earth.

6.1. Normal Operating Conditions

In the absence of the power line fault, the system is sinusoidal and balanced. The existence of the voltages and currents at the two ends of the line (on buses 2 and 7) is shown in the Fig. 8.

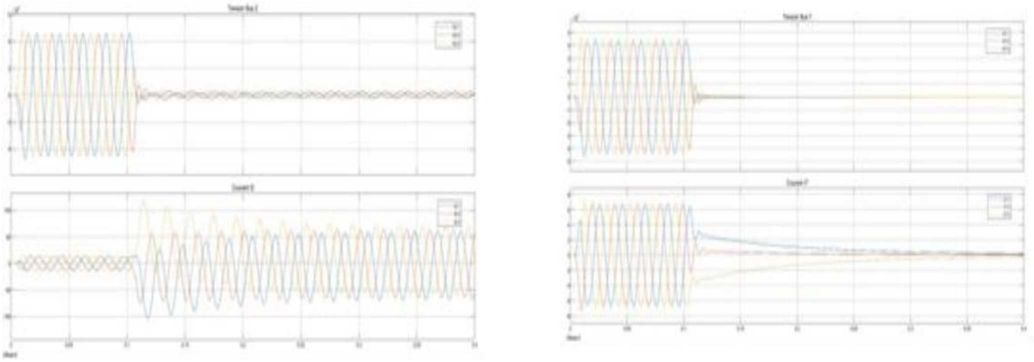


(a) At Bus Bar 2 (b) At Bus Bar 7

Figure 8. Voltage and current transmission under normal conditions

6.2. Three Phase Faults

The Fig. 9 presents the voltage and current simulations for a three-phase fault at 25 km from Lutchurukuru. Thus, it is noticed an abrupt voltage decrease and a sudden current increase after 0.1 sec run when the fault appeared.



(a) At Bus Bar 2 (b) At Bus Bar 7

Figure 9. Voltage and current transmission under three phase faults

Referring to the radial configuration (Single Power Line Diagram in Fig.6), the following observations are made:

- The fault closer to the sources (Bus 2) will be the most dangerous because it presents a very large fault current.
- As the fault moves away from transmitting end (Bus 2), both the voltage and the current decrease during the fault occurrence.

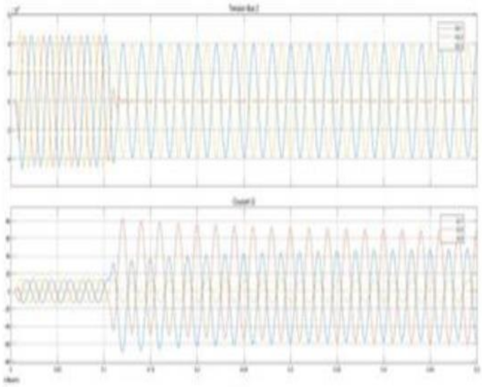
Table 3 presents the measured data collected at the transmitting end (Bus 2) and the receivingend (Bus 7)across various locations.

Table 3.Data measured at different locations.

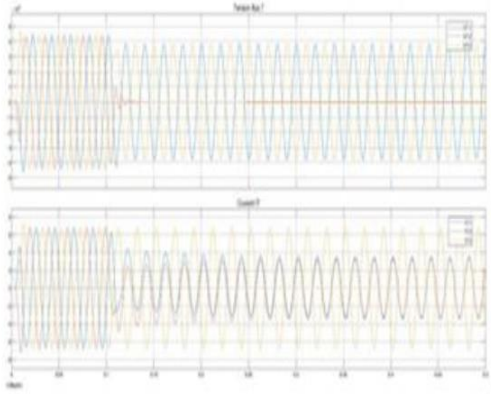
Bus 2		Bus 7		Location
Voltage (kV)	Current (A)	Voltage (kV)	Current (A)	km
0.0667	49.15	0.006	0.13	
0.0664	47.26	0.003	0.024	1
0.0669	48.5	0.009	0.104	
1.5917	45.2441	0.01013	0.27	
1.5905	45.178	0.0688	0.05	25
1.5908	45.2455	0.02	0.21	
3.052	43.25	0.011	0.32	
3.051	43.25	0.05	0.0655	50
3.051	43.25	0.017	0.2586	
4.4011	41.49	0.087	O.39	
4.401	41.498	0.042	0.08	75
4.40	41.498	0.013	0.31	
5.41	40.18	0.04	0.46	
5.41	40.18	0.02	0.099	95
5.40	40.19	0.06	0.326	

6.3. Two Phase Faults

The Fig. 10 shows the bus voltage and line currents during two phase faults located at 1 km away from Bus 2. As it can be seen the signals are no longer periodic and the system is unbalanced. The effective values vary according to the fault location.



(a) At Bus Bar 2



(b) At Bus Bar 7

Figure 10. Voltage and current transmission under two phase faults

Referring to the radial configuration (Single Power Line Diagram in Fig.6), the following observations are made:

- Two phases remain powered unlike the three-phase fault;
- The absence of voltage in the third phase.

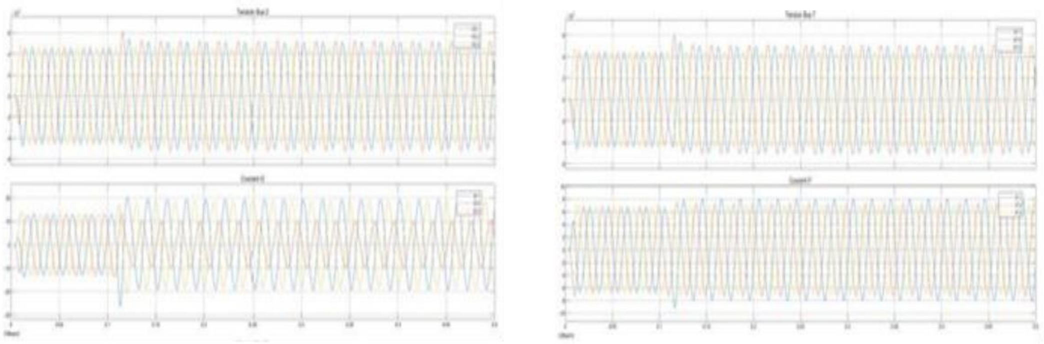
Table 4 presents the measured data collectedat the transmitting end (Bus 2) and the receiving end (Bus 7) across various locations.

Table 4. Data measured at different locations.

Bus 2		Bus 7		Location
Voltage (kV)	Current (A)	Voltage (kV)	Current (A)	km
27.838 0.066 27.821	9.1558 45.5244 36.6604	26.926 0.0033 26.926	4.7757 2.3867 2.3897	1
28.203 3.0517 27.535	9.1587 41.9228 33.1006	26.925 0.003 26.925	4.7758 2.3867 2.3909	25
28.029 3.0159 27.534	9.1578 43.5960 34.7281	26.925 0.003 26.924	4.7754 2.3865 2.23901	50
28.345 4.4026 27.4556	9.1529 40.3606 31.5933	26.912 0.002 26.912	4.7752 2.3865 2.23904	75
28.461 5.410 27.434	9.1517 39.2081 30.48	26.916 0.001 26.916	4.77 2.3878 2.3916	95

6.4. Single Phase Fault

The Fig. 11 shows the bus voltage and line currents during single phase fault located at 1 km away from Bus 2. As it can be seen the signals are no longer periodic and the system is unbalanced. The faulty phase (phase A in our case) suffers a drop in voltage and an overcurrent.



(a) At Bus Bar 2 (b) At Bus Bar 7

Figure 11. Voltage and current transmission under single phase faults

Referring to the radial configuration (Single Power Line Diagram in Fig. 6), the following observations are made:

- The voltage between the different phases becomes large compared to the normal operation of the network;
- The faulty phase is overcurrent and its voltage drops compared to that of the other phases.

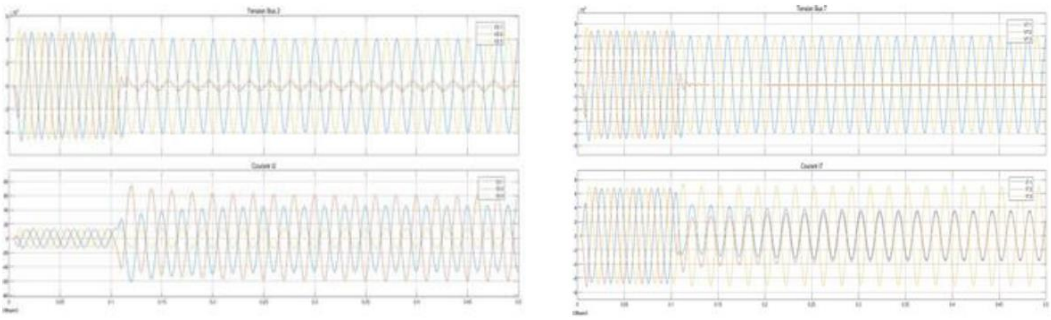
Table 5 presents the measured data collectedat the transmitting end (Bus 2) and the receiving end (Bus 7) across various locations.

Table 5. Data measured at different locations.

Bus 2		Bus 7		Location
Voltage (kV)	Current (A)	Voltage (kV)	Current (A)	km
32.13	13.1062	31.089	4.907	
36.915	6.754	35.7226	5.0878	1
35.799	13.5636	34.642	5.6023	
32.149	13.057	31.10	4.8979	
36.88	6.8692	35.92	5.109	25
35.66	13.5719	34.668	5.6243	
32.153	13.0164	31.109	4.889	
36.837	6.97	36.124	5.1302	50
35.563	13.5925	34.688	5.641	
32.154	12.988	31.109	4.8795	
36.805	7.0632	36.331	5.1513	75
35.459	13.6341	34.713	5.6698	
32.133	12.9677	31.089	4.8694	
36.76	7.122	36.480	5.1663	95
35.363	13.6776	34.722	5.6862	

6.5. Double Phase to Ground Faults

A fault between two phases and ground is different from a two phases fault because the faulty conductors touch the earth. The Fig.12 shows the bus voltage and line currents during double phase to ground fault located at 1 km away from Bus 2. As it can be seen the signals are no longer periodic and the system is unbalanced. The faulty phase (phase A in our case) suffers a drop in voltage and an overcurrent. The fault closer to Bus 2 leads to an overcurrent and drop in voltage atBus 2. When the fault moves away from Bus 2, the current drops and the voltage rises.



(a) At Bus Bar 2 (b) At Bus Bar 7

Figure 12. Voltage and current transmission under double phase to ground faults

Referring to the radial configuration (Single Power Line Diagram in Fig.6), the following observations are made:

- Two phases remain powered with unwanted voltages;
- The third phase presents a low voltage and an overcurrent.

Table 6 presents the measured data collectedat the transmitting end (Bus 2) and the receiving end (Bus 7) across various locations.

Table 6. Data measured at different locations.

Bus 2		Bus 7		Location
Voltage (kV)	Current (A)	Voltage (kV)	Current (A)	km
28.973	9.4827	28.030	4.9756	
0.066	45.7980	0.003	2.4862	1
28.956	36.4016	28.03	2.4901	
28.795	9.5075	27.707	4.9	
1.5911	43.86	0.0032	2.4535	25
28.425	34.488	27.707	2.4572	
29.215	9.6953	28.011	4.9675	
3.0531	42.3325	0.003	2.4822	50
28.573	32.6808	28.011	2.4865	
29.473	9.7715	28.186	4.9977	
4.4017	40.8369	0.00218	2.4974	75
28.627	31.1164	28.186	2.5020	
29.683	9.7218	28.322	5.0344	
5.4104	39.6531	0.0011471	2.5160	95
28.665	29.9890	28.322	2.5208	

6.6. Circuit Breaker Selection

After analysing all the faults along the line, it was found that the three-phase fault is the most dangerous because it has the greatest fault current measured at Bus 2. Using data from normal working voltages and fault currents the circuit breakers to be placed respectively at the transmittingend and receiving end of the line are presented in the following table 7 and table 8 respectively.

Table 7. Circuit breaker characteristics at the transmitting end (Bus 2)

Normalized Voltage	34.5 kV
Steady State Current	9.4 A
Sub transient Fault Current	49.15 A
Number of Cycles for Interruption Time	5
Breaking Capacity	4.376 MA
Maximum Instantaneous Current	139.017 A
Maximum Value of DC Component	69.5 A
Momentary Current	78 A
$S_{momentané}$	4.376 MVA

Table 8. Circuit breaker characteristics at the receiving end (Bus 7)

Normalized Voltage	34.5 kV
Steady State Current	4.77 A
Sub transient Fault Current	5.6 A
Number of Cycles for Interruption Time	5
Breaking Capacity	497.5 kA
Maximum Instantaneous Current	15.84 A
Maximum Value of DC Component	8 A
Momentary Current	8.96 A
$S_{momentané}$	482.41 VA

$S\ momentané$: time-varying value of apparent power

7. CONCLUSION

The presented results in this paper deal with the analysis of numerous types of faults and selection of circuit breakers for the protection of power lines. To determine the behaviour of the network during transient conditions, the power line network model and its simulation were carried out using Simscape power tool box available in Simulink. Hence, referred to the measured data in table 3, the three phase fault at figure 9, has been identified as the most dangerous fault because it generates a greater fault current at the transmitting end (Bus 2). Hence, the data collected during the three-phase fault analysis were used to decide on the characteristics of the circuit breakers to deploy in both transmitting and receiving ends of the 105 km long radial overhead power line power from Lutchurukuru to Kindu.

ACKNOWLEDGMENTS

Authors would like to thank the School of Electrical and Communications Engineering at the Papua New Guinea University of Technology (Unitech) for funding the publication of this paper.

REFERENCES

[1] T. Gonen, “Alectric Power Transmission System Engineering Analysis and Design,” New York: CRC Press.
[2] S. H. a. F. Ayalew, “Fault Detection, Protection and Location on Transmission Line,” Researchgate, p. 9, 21 decembre 2021.
[3] S. A. Nasar, “Theory and Problems of Electric Power Systems,” McGRAW-HILL.
[4] V. M. e. R. Mehta, “Principles of Power System,” S. CHAND.

[5] D. Snel, “Interviewee, Protective equipement for the Lutchurukuru Kindu power Line.” [Interview]. 24 January 2024.
[6] B. Mohamed, “Coordination des Systemes de Protection,” Algérie : Universite Constantine 1, 2013.
[7] O. S. e. al, “Signal Behaviours of Power Transmission Line During Fault,” IRE Journals, 2019.
[8] T. B. Satish Karekar, “A Modelling of 440 kV EHV Transmission line faults identified and analysis by using MATLAB Simulation,” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering , p. 8, 3 March 2016.
[9] H. Saadat, “Power System Analysis,” McGraw-Hill.
[10] R. Kumar, “Three Phase Transmission Lines Fault Detection, Classification and Location” ISJR, p. 4, 2013.
[11] E. D. O. A. A. Abdullahi Afwah, “Three-Phase Fault Analysis on Transmission line In MATLAB SIMULINK,” IJESRT, p. 4, 2019.
[12] M. D. P. a. M. P. J. Mr. Sandesh Gaikwad, “Basic Matlab Simulation of Faults within Power System” International Journal of Engineering Sciences and Research Technology , p. 7, May 2020.
[13] A. N. A. S. S. Akshit Sharma, “Fault Analysis on three phase Transmission lines and its detection,” International Journal of Advance Research and Innovation , p. 5, 15 June 2017.
[14] Y. O. P. A. O. O.-S. O. Naenwi, “Analysis of Three- Phase Transmission Line FaultUsing Matlab/Simulink,” International Journal of advances in Engineering and Management (IJAEM), p. 8, 13 07 2021.
[15] T. M. Rimsha Fazaln Habib Ullah Manzoor, “Analysis of Relay Protection System Compârison for Better Identification InHigh Voltage AC Transmission Lines,” Research Square, p. 16, 22 November 2021.
[16] B.Lazhar, “Protection des réseaux électriques,” Algérie : Université Echahid Hamma Lakhdard'EL Oued, 2017.
[17] S. R. M. S. h. a. s. Mehfuz, “Experimental studies on impedance based fault location for long transmission line,” SpringerOpen, p. 9, 2017.
[18] T. S. Kawady, “A practical fault location approach for double circuit transmission lines using using single end data.,” IEEE Transactions on power delivery , pp. 18, 1166-1173, 2003.
[19] J. a. S. M. Izikowski, “Locating faults in parallel transmission line under availibilityoat of complete measurement at one end,” IEEE proceedings - Generation Transmission and distribution , pp. 151, 268-273, 2004.
[20] R. M. Izykowski, “Fault location on double circuit series-compensated lines using two end unsynchronised method measurement,” IEEE transactions on power delivery. , pp. 2072-2080, 2011.
[21] V. M.P. Thrake, “Distance Protection for Long Transmission Line using Pscad,” International Journal of Advances in Engineering ang Technologie, pp. 2579-2586, January 2014.
[22] C. Prévé, “Protection of Elecrical Network,” 2006.
[23] N. e. al, “Analysis of Three Phase Transmisssion Line Fault using Matlab/Simulink,” IJAEM, p. 8, 2021.
[24] M. Y. N. K. S. Boora, “Matlab Simulation Based Study of Various Types of Faults Occuring in the transmission Lines,” IJERT , p. 4, 12 December 2019.
[25] S. C. e. al, “Transmission Line Faultanalysis by using Matlab Simulation,” IJESRST, p. 4, 2015.
[26] J. D. Glover, “Power System Analysis and Design,” CENGAGE Learning.
[27] S. A. Nasar, “Theory and Problems of Electric Power Systems,” McGRAW- HILL, New York, 1990.