Performance Evaluation of the Distance Relays at the Edo Region for 132kV Transmission Network

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Abstract- This study was carried out to determine the performance evaluation of the distance relays at the Edo region of the 132 kV Transmission network from the Benin transmission centre. The research assesses the performance of the Edo relays, R_1 and R_2 at the Irrua, Okpilla and Irrua-Etsako lines. The methodology used in this research involves a power flow and a short circuit studies as well as using the quadrilateral characteristic to determine the relay impedance, Z_R at the R-X plane of the Irrua- Etsako line. The short circuit analysis and the power flow study of the distance relays was carried out using the data obtained from Transmission Company of Nigeria (TCN) for this network as input. The input data are: Voltage Transformer rating of 132 kV, Power Transformer rating of 90 MVA, Current Transformer with a rating of 400 A, Current Transformer ratio of 400/1 A, Resistance/kilometer of 0.222 ohm/km and Reactance/kilometer of 0.4281 ohm/km. Neplan software was used to simulate the network starting from Benin TCN using the data gathered from TCN Benin Transmission Centre. The results obtained showed that relay 1 (R_1) and the relay 2 (R_2) at zone 2 had an un-instantaneous tripping action at a delayed tripping time of 0.4 s for relay 1. For relay 2, there was an instantaneous tripping action at 81-99% fault distances at zone 2 end and zone 3 entrance. Hence, for the Irrua and the Okpilla lines, the relay 1 (R_1) at zone 1 during the three-phase fault had a fast tripping time of 0.4 s at the entrance to the line and an un-instantaneous tripping action of 0.1 s at 60-80% fault distances at zone 1 end. In conclusion, the Irrua-Etsako and Okpilla lines had an instantaneous tripping action during the three-phase fault due to the slow tripping of relay 1 (R_1) and the fast tripping of relay 2 (R_2) at zone 1 and 2 respectively. This caused the distance relays to malfunction due to the high fault current of magnitude 3.238 kA and 2.901 kA at the faulted lines causing low impedances experienced by the distance relays at the Irrua-Etsako and Okpilla lines.

Indexed Terms- Performance, Evaluation, Distance Relay, Edo Region, Transmission, faulted line etc.

I. INTRODUCTION

The distance protection scheme is normally applied to protect transmission lines. It acts as the main protection for overhead transmission lines. It also functions as a backup protection to the linking parts of the network such as bus bars, transformers, circuit breakers, switch gears, protection relays and feeder lines [7]. Distance protection is faster and more selective than over-current protection. It is also less prone to fluctuations in the power system conditions. An additional benefit of the distance protection is that it can be adapted easily to a unit protection scheme when applied with a communication connection [12]. Basically, a distance relay controls the impedance of the faulted portion of a transmission line from the measured voltages and currents at the relay location. Distance relay is generally used for medium and long transmission lines [1]. The distance relay calculates the impedance using voltage and current parameters to determine if the fault is within the protection zone or outside the protection zone of the transmission line network. When the measured fault impedance is matched with the impedance of the transmission line to be protected, one can determine if a fault exists on the transmission line between the relay and the fault point or not [1]. If the measured fault impedance is lesser than the impedance of the transmission line, it means that a fault exists on the transmission line between the relay and the fault point (vice-versa). This suggests that the distance protection method can reach a protection decision with the measured voltage and current at the relay location [8].

[9] added that achieving a distinct protection scheme will be possible through an integration of modern interconnected elements. The modern interconnected

elements should lead to the high decision making and tripping time of the relay during fault condition.

II. DISTANCE RELAY PERFORMANCE

Distance relay performance is defined in terms of reach accuracy and operating time [11].. Reach accuracy is an assessment of the actual reach of the relay under practical conditions with the relay setting value in ohms [11]. Reach accuracy is commonly dependent on the level of voltage presented to the relay under fault conditions. The impedance measuring techniques employed in particular relay designs have great impact on the distance relay performance. The operating time of the relay can vary with fault current, fault position relative to the relay setting and the point at which the fault occurs [11]. Measured transient signal errors like that produced by the Capacitor Voltage Transformers (CVTs) or Saturated Current Transformers can adversely affect delay relay operation for faults nearest to the reach point [4]. For a fault at the reach point, this may be alternatively expressed in terms of source to line impedance ratio $\frac{Z_S}{Z_L}$ using the following expressions:

$V_R = I_R Z_R = I_R(Z_L + Z_S)$ where, $Z_R = Z_S + Z_L$ and $I_R = \frac{V_R}{Z_S + Z_L}$

(2.1)

where, I_R = Relay current; V_R = Relay Voltage; Z_L = Line Impedance; Z_S = Source Impedance and V = Total voltage [2].

III. MATERIALS AND METHOD

The following materials were collected as data from the Transmission Company of Nigeria (TCN), Benin and it was used to carry out the power flow study and the short circuit analysis for the 132 kV transmission network. The data collected are: (i) The Aluminium Conductor Steel Reinforced with galvanized (ACSR/GZ) Transmission line conductors on steel tower supports. (ii) Voltage Transformer rating of 132kV) (iii) Power Transformer whose rating is90 MVA (iv) Current Transformer with a ratings of 400A, 600A and 800A were used as various points of the lines (v) Current Transformer ratio with a ratings of 400/1A, 600/1A and 800/1A. (vi) Resistance/kilometer of 0.222ohm/km and (vii) Reactance/kilometer of 0.4281ohm/km. Neplan software was used to carry out the short circuit analysis and the power flow study of the distance protection network. The distance relay at the Edo region was examined using Neplan software. The case study had its network connecting Benin-Irrua, Irrua-Etsako, Etsako-Okpilla to Okpilla-Okene through Okene-Ajaokuta, Ajaokuta-Itakpe terminating at Itakpe transmission bus on the first layer of the network.

To convert the primary impedance, $Z_{Pri.}$ to secondary impedance, $Z_{Sec.}$ in order to set a distance relay, the following expression was used in the form of an equation:

$$Z_{Sec.} = Z_{Pri.} * \frac{CTR}{VTR} \quad (3.1)$$

where, CTR and VTR are the current and potential transformer turn ratios, $Z_{Pri.}$ and $Z_{Sec.}$ are primary impedance and secondary impedance of the line [3].

$Z_1 = 0.2220 + j0.4189 = 0.474\Omega/km$ [6].

$Z_2 = 0.2450 + j0.5822 = 0.632\Omega/km$ [7].

$Z_0 = 0.4639 + j1.2986 = 1.379\Omega/km$ [5].

3.1 Neplan Software

Neplan is one of the major power system analysis software tools that can be used to analyze, simulate, plan and optimize electric power networks. Neplan has a Graphic User Interface (GUI) that is very user-friendly and it covers the three aspects of power systems. Neplan has a vast model library for thousands of network elements. It uses advance algorithms for dynamic simulations and it supports real time simulations of the models created in Matlab/Simulink directly. The reason why Neplan software was used was because users can develop elements in Matlab/Simulink and can simulate it using Neplan environment because it has a very effective import/export interface (verse-versa) Hence, Neplan software was chosen for computing fault current at different buses where the fault condition had occurred.

Table 3.1: Line parameters for the 132 kV transmission network.

Lines	Line Length (Km)	Actual Power (MVA)	Circuit Type
Benin-Irrua	81	90	Double Circuit
Irrua-Etsako	23	90	Single Circuit
Etsako-Okpilla	20	90	Single Circuit
Okpilla-Okene	33	15 - 30/40	Single Circuit
Okene-Ajaokuta	60	90	Double Circuit
Okene-Itakpe (T-off/Itakpe)	41.7	90	Double Circuit
Ajaokuta-Itakpe	45	90	Single Circuit
Ajaokuta-Ajaokuta Town	10	90	Single Circuit

Table 3.2 gives a summary of the calculated sequence impedances used for this research. The various positive, negative and zero sequence impedances across the Edo layer of the network were used for relay setting of the distance relay. The zero sequence impedances from Benin to Irrua, Irrua to Etsako, Etsako to Okpilla, Okpilla to Okene and from Okene to Ajaokuta were responsible for the mal-operation of the distance relay. The effect of the zero sequence impedances caused a change in the zero sequence current components, which in turn increases the fault current causing the mal-operation of the distance relay.

Table 3.2: The Sequence impedances of the conventional distance relays.

Lines	Positive Sequence Impedance, $Z_1(\Omega)$	Negative Sequence Impedance, $Z_2(\Omega)$	Zero Sequence Impedance, $Z_0(\Omega)$
Benin-Irrua	38.39	51.19	111.70
Irrua – Etsako	9.48	12.64	27.58
Etsako Okpilla	10.90	14.54	31.72
Okpilla-Okene	15.64	20.86	45.51
Ajaokuta	19.77	26.35	57.50

IV. Results and Discussion for the Investigation of the performance of the132 kV Edo Region of the Benin Transmission Network.

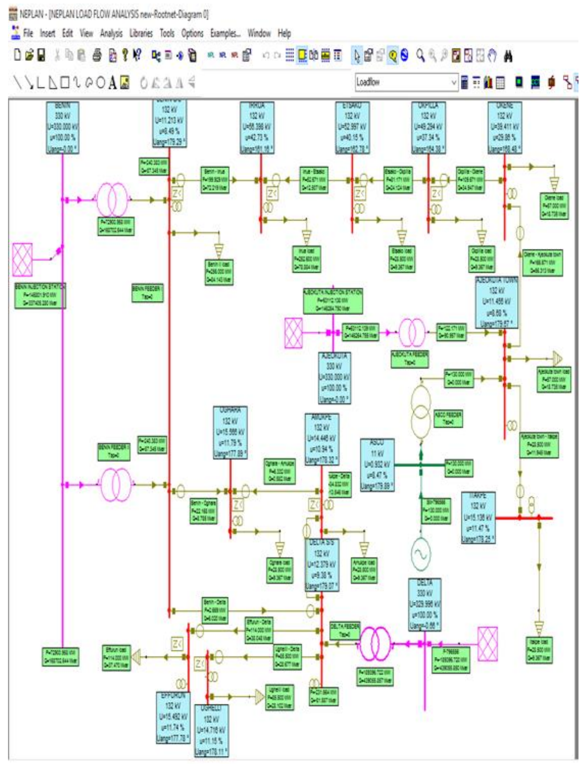


Figure 4.1: A snapshot of the power flow of the 132 kV buses in Neplan environment. [10].

From figure 4.1, power flows from the 330 kV Mains to the Benin 132 kV transmission bus. The power flows through the Benin 132 kV bus bar with 653 MVA transmitted to the Irrua bus having 286.013 MVA. There was a reduction in power to 281.840MVA at Irrua-Etsako transmission line before the Etsako 132 kV. The power then flows through the Etsako-Okpilla transmission line at 4.633MVA power. And then, a power of 406.364MVA flows at the Okpilla 132 kV transmission line. The power then flow to the Okpilla-Okene line with a power of 402.190 MVA.

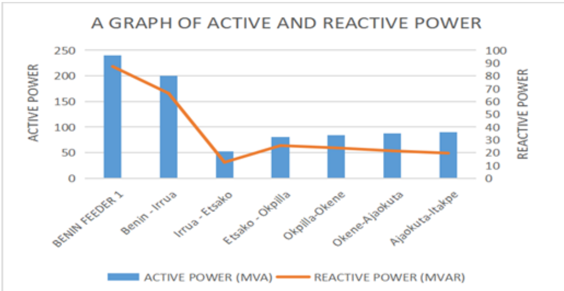


Figure 4.2: A graph of active and reactive power flow.

From figure 4.2, the active power flows were very high at the Benin feeder 1 and Benin-Irrua bus due to a drastic reduction in load demand. The active power values at the Benin feeder 1 and Benin-Irrua 230 MVA and 200 MVA respectively. The reactive power values in MVARs were about 83 MVAR and 70 MVAR respectively. The implication of the high active power is considered with respect to electrical load. It means that the connected load or device consuming power are drawing significant amount of energy to perform their intended function which can lead to increased stress on the power network. This high active power can lower the efficiency in an electrical network due to the losses incurred during waste leading to resistive losses in transmission lines. The high active power flow also causes a significant voltage drop leading to reduced performance or malfunctioning of the distance relay.

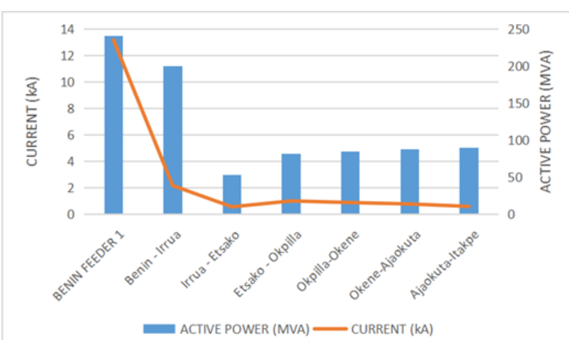


Figure 4.3: A graph of active power and fault current.

From figure 4.3, the active power flows were very high at the Benin feeder 1 and Benin-Irrua bus due to a drastic reduction in load demand. The active power values at the Benin feeder 1 and Benin-Irrua were 230 MVA and 200 MVA respectively. The fault current values in kA for Benin feeder 1 and Benin-Irrua were about 13 kA and 2.3 kA respectively. The implication of the high fault current is that it disrupts the normal operation of the electrical network. However, the high fault current requires longer interruption times or may exceed the interrupting capacity of the circuit breaker (protective device) leading to extended power outages and system downtime.

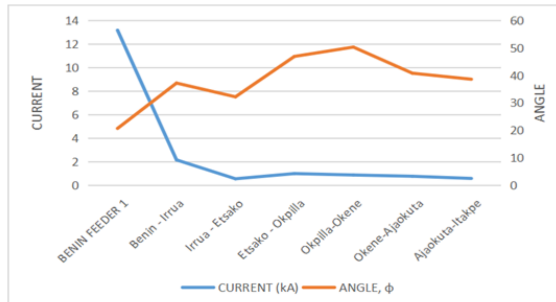


Figure 4.4: A graph of current and Phase angle.

From figure 4.4, there was a peak current of about 13.2 kA at Benin feeder I and Benin-Irrua line. The current values at other buses were affected by the changes in the angle of displacement between current and voltage at the buses. When there is a change in the current values, there will also be a corresponding change in voltages and angle of displacement across the various buses.

4.1 Short Circuit study of the faulted line for the 132kV Transmission network

A short circuit study of the 132 kV Benin Transmission Network was carried out at the different buses using Neplan software. A three-phase fault occurred at the Irrua bus, Okpilla bus and the Irrua-Etsako transmission line. A yellow coloured line was used to indicate the location of the fault at the line.

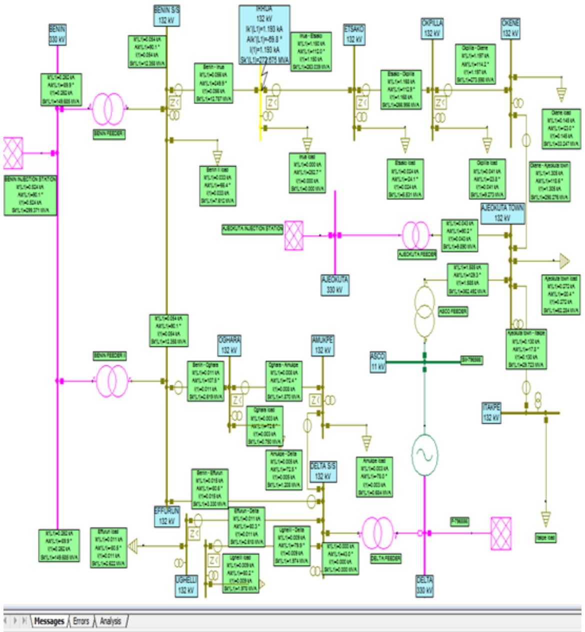


Figure 4.7: A Short Circuit Simulation Diagram of the Benin 132 kV Transmission Network with fault at Irrua bus using Neplan Software.

From figure 4.7, power is supplied from the Benin 330 kV mains through the Benin feeder to the Benin 132 kV transmission substation (S/S). The Benin 132 kV bus supplies the Irrua 132 kV line linking Etsako 132 kV line, Okpilla 132 kV line, Okene 132 kV line, Ajaokuta 132 kV line and finally terminates at Itakpe 132 kV transmission line. For the faulted Irrua bus, the current transformer, voltage transformer and the conventional distance relay was used. The current transformer ratio was 400/1A and that of the voltage transformer was 132/0.1kV at a frequency of 50Hz. The evaluation of the relay tripping was carried out with the positive sequence impedance. When the Irrua transmission bus is at fault, a short circuit current of 1.373kA (1,373A) flows through the Irrua-Etsako transmission line.

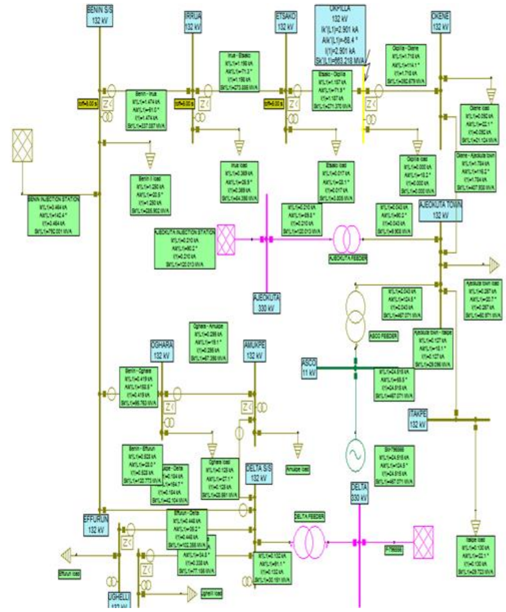


Figure 4.8: A Short Circuit Simulation Diagram of the Benin 132 kV Transmission Network with Fault at Okpilla bus using Neplan Software.

Figure 4.8 showed that Okpilla bus was faulted and the faulted bus was indicated with yellow coloured line. The yellow coloured line showed that there was a short circuit current flow at the Okpilla bus. The short circuit current that flows through the Okpilla-Okene transmission line increased significantly to 1.759 kA (1,759A). From table 1, it was observed that the fault current for other lines were not very high when compared to Irrua-Etsako line, Okpilla-Okene line and Ajaokuta town line, which had very high fault current values because of very low impedance between the relay point and the fault point on the transmission line. For the faulted Okpilla bus, the current transformer, voltage transformer and conventional distance relay was used. The current transformer ratio was 400/1A and that of the voltage transformer was 132/0.1kV at a frequency of 50Hz. The evaluation of the relay tripping was carried out with the positive sequence impedance, z_1. The characteristic for setting was polygon.

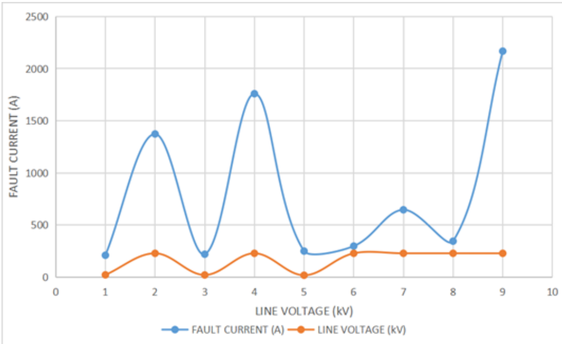


Figure 4.9: Fault current and line voltage.

Figure 4.9 shows the relationship between fault current and line voltage. The fault current increased suddenly at Irrua-Etsako line, Okpilla-Okene line and Ajaokuta town line respectively. While, the line voltage decreased correspondingly. From figure 4.11, it was observed that the line voltage increased greatly for the Benin-Irrua and Okene-Ajaokuta lines. Though, the fault current was high at other transmission lines, it was discovered that the fault current was highest at the Ajaokuta town line due to the severity of the three-phase fault. The high fault current was due to the malfunctioning of the relay and insulation failure of the cables. The high fault current resulted to overheating of equipment and conductors.

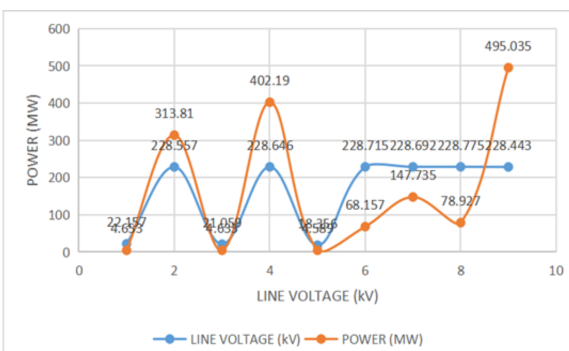


Figure 4.10: Power and Line Voltage.

From figure 4.10, the power and line voltage were analyzed and it was observed that the line voltage was moving steadily, while the fault current was steady at other buses until it increased suddenly at Irrua-Etsako and at Ajaokuta Town 132 kV transmission lines. The power flows from the Benin-Irrua through other lines to Ajaokuta town line. At Irrua-Etsako line, the power was the same at 313.81 MW. It then remained the same at 402.19 MW at Okpilla-Okene line. The line voltage remained steady within a permissible range between 128 kV and 144 kV along all the buses.

4.2 Benin-Irrua distance relay setting at the R-X plane.

For the zone one (1) setting of the conventional distance relay when there was no fault, the resistance (R) and the reactance (X) are 43.60 ohms and 82.10 ohms respectively from the R-X plane of the polygon characteristic as shown in figure 4.12. Hence, the impedance at no fault condition is 92.96 ohms. Only zone one (1) was activated; while other zones remained inactivated. During the three-phase fault, the circuit breaker opening time was 0.02 second.

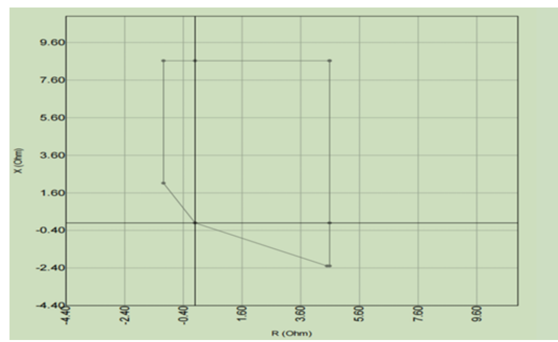
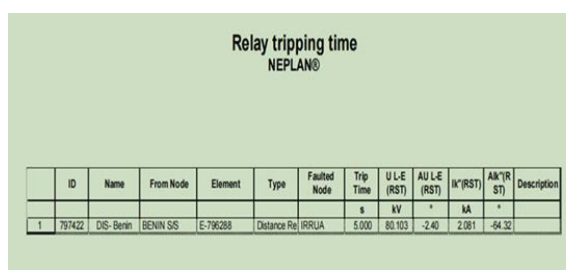


Figure 4.11: Characteristic Impedance for Benin Relay for three-phase fault at 75% of Irrua line.

From figure 4.11, for zone one (1) at the Irrua bus, the conventional distance relay has to be set at a value that can initiate a faster trip response. When fault occurred at the Irrua line, the resistance (R) was equal to 4.54 ohms and the reactance (X) was 8.61 ohms respectively. The current at fault location (Irrua bus) was 3.238 kA and the power MVA rating was 740.337 MW. The resistance of the Irrua line is 70.579 ohms.


Relay tripping time
NEPLAN®

	ID	Name	From Node	Element	Type	Faulted Node	Trip Time	U L-E (RST)	AU L-E (RST)	Ik"(RST)	AIk"(RST)	Description
							s	kV	°	kA	°	
1	797422	DIS- Benin	BENIN S/S	E-796288	Distance Re	IRRUA	5.000	80.103	-2.40	2.081	-64.32	

Figure 4.12: Tripping time of the Benin Relay for three-phase fault at 75% of Irrua line.

From figure 4.12, the distance relay had a low voltage level at the faulted Irrua bus, where the fault occurred was 80.103kV due to the sudden rise in the current magnitude to an arbitrary value that caused hazard to several equipment such as the power transformers, voltage transformers, current transformers, circuit breakers and eventually caused the relay to malfunction.

Currents at fault locations
NEPLAN®

	ID	Fault location	Un	Ik"(RST)	AIk"(RST)	Ik (RST)	Sk"(RST)	Fault	Method	Maximum	Network	CB delay time	SC duration	SC duration
			kV	kA	°	kA	MVA	type		current	type	s	s	s
1	795787	IRRUA	132.000	3.238	-65.69	3.238	740.337	3phase fa	Superpos.	☒	MESHED	0.020	1.000	0.020

Figure 4.13: Fault Current for three-phase fault at the Irrua line.

Figure 4.13 shows a graph of fault current for the three-phase fault at the Irrua line. It showed the fault location at 132 kV line voltage with a fault current of 3.238 kA at an angular displacement of 65^0 in the reverse direction because of the negative sign of the angle between the fault location and the relay point. The power measured during the three-phase fault is 740.337MVA. Superposition method was used in a meshed network type. The circuit breaker delay time is 0.02 second. While, the short circuit duration lasted for 0.02 second.

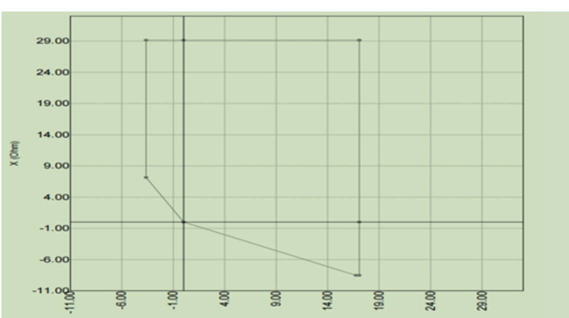


Figure 4.14: Characteristic Impedance for Benin Relay for three-phase fault at 75% of Irrua line, 25% of Etsako line and 50% of Okpilla line.

Figure 4.14 showed the characteristic impedance for the Benin relay for the three-phase fault that occurred at 75% of Irrua line, which means that the tripping of the relay at zone one (1) was at 0.75 times the relay impedance, Z_R. The value gives the actual impedance of the distance relay. Hence, when the impedance characteristic is at 25% of Etsako line, which means that the distance relay can trip at a 100% (at the point of unity). Furthermore, the distance relay tripping schedule for the Okpilla line was for 125%, which means that 100% of the entire line plus a backup of 25% for the Okpilla line.

Relay tripping time
NEPLAN®

	ID	Name	From Node	Element	Type	Faulted Node	Trip Time	U L-E (RST)	AU L-E (RST)	Ik"(RST)	AIk"(RST)
							s	kV	°	kA	°
1	797422	DIS- Benin	BENIN S/S	E-796288	Distance Re	OKPILLA	5.000	80.856	-2.28	1.474	-61.04
2	797431	DIS- Irrua	IRRUA	E-795792	Distance Re	OKPILLA	5.000	24.306	-9.53	1.198	-71.32
3	797440	DIS-Etsako	ETSAKO	E-795795	Distance Re	OKPILLA	5.000	9.666	-9.87	1.187	-71.89

Figure 4.15: Tripping time of the Benin Relay for three-phase fault at 75% of Irrua line, 25%of Etsako line and 50% of Okpilla line.

From figure 4.15, the trip time was 5s, the voltage at the Irrua and the Etsako buses is 24.305kV and 9.666kV. The fault current for the Irrua and Etsako buses are 1.198 kA and 1.187 kV. The implication of this is that the low voltages at the buses at the time of fault caused the mal-operation of the distance relay.

Currents at fault locations
NEPLAN®

	ID	Fault location	Un	Ik"(RST)	AIk"(RST)	Ik (RST)	Sk"(RST)	Fault	Method	Maximum	Network	CB delay time	SC duration	SC duration
			kV	kA	°	kA	MVA	type		current	type	s	s	s
1	795789	OKPILLA	132.000	2.901	-68.36	2.901	663.218	3phase fa	Superpos.	☒	MESHED	0.020	1.000	0.020

Figure 4.16: Fault Current for three-phase fault at the Okpilla line.

From figure 4.16, the time delay was 0.02 s and the short circuit fault duration was 0.5 s before the occurrence of the fault at the Okpilla bus. The fault inception angle for the Okpilla bus was 68.36 degrees. For the Okpilla 132 kV transmission station, the current at fault location at Okpilla bus was 2.901 kA and the power MVA rating of the three-phase transformer was 663.218 MW. The resistance of the Okpilla line is 78.81 ohms. The network type used was mesh network.

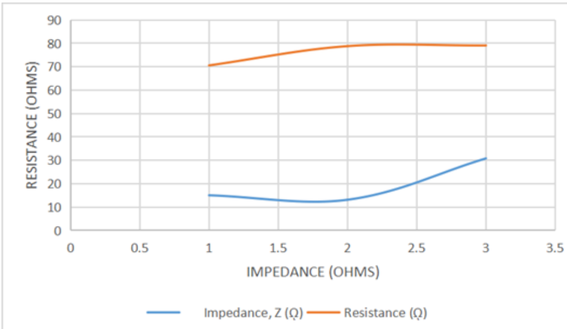


Figure 4.17: Impedance and resistance at the first layer of the transmission network.

From figure 4.17, it was observed that the resistance increased when the impedance decreased. As soon as the resistance begins to decrease, the impedance starts increasing. Each impedance value for other lines also increases as well.

Also, the fault occurred at the Irrua and Okpilla transmission bus, the fault current increased unfavorably to an arbitrary value of 3.238kA and 2.901kA respectively. This made the impedance of the transmission line to drop at the Irrua bus thereby making the relay nearest to the fault location to trip in order to isolate the bus or the transmission line from any form of damage.

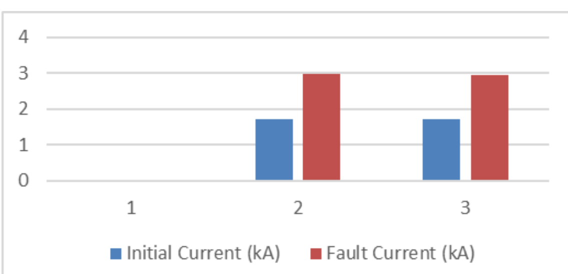


Figure 4.18: Initial current and fault current at Irrua line

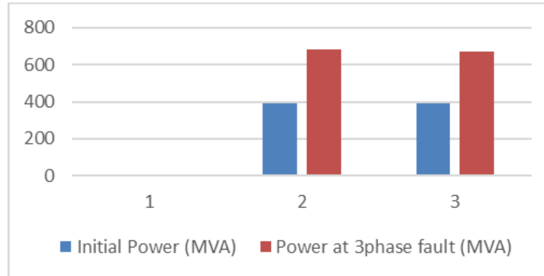


Figure 4.19: Initial power and power after three-phase fault occurred at Irrua bus.

Figures 4.18 and 4.19 are graphs plotted to explain the initial values of current and power as well as the three-phase values of current and power shown in Table 4.1 and Table 4.2.

Table 4.1: Initial Power and current after three-phase fault occurred at 60-80 % and 81-99 % fault distances at the Irrua-Etsako line.

Faulted line	Fault Distance (%)	Initial Current (kA)	Initial Power (MVA)
Irrua-Etsako	60-80	1.710	391.003
Irrua-Etsako	81-99	1.710	391.003

Table 4.2: Power at three-phase fault and Fault current at 60-80 % and 81-99 % fault distances at the Irrua-Etsako line.

Faulted line	Fault Distance (%)	Fault Current (kA)	Power at three-phase fault (MVA)
Irrua-Etsako	60-80	2.991	683.767
Irrua-Etsako	81-99	2.935	670.948

Table 4.3: Relay operating time at 60-80 % and 81-99 % fault distances at the Irrua-Etsako line.

Faulted line	Fault Distance (%)	Relay operating time (sec)	
		R_1	R_2
Irrua-Etsako	60-80	0.4	0.10
Irrua-Etsako	81-99	0.4	0.13

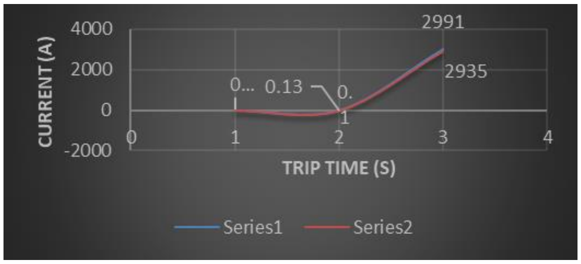


Figure 4.26: Relay operating time when fault occurred at Irrua-Etsako line.

Figure 4.26 is a graph plotted to explain the relay operating time for relay 1 and Relay 2 at 0.4 second and 0.10 second at 60-80% fault distance. Also, the relay operating time for relay 1 and Relay 2 at 0.4 second and 0.13 second at 81-99% fault distance.

4.3 Performance of the Edo distance relay at the Edo Side of the Network

In order to evaluate the performance of the Edo distance relay, the three-phase fault. the operating time of relays, R_1 and R_2 at both end of the Irrua-Etsako line were analyzed. The results of the three-phase fault conditions as presented in Table 4.2 gives a summary of the performance of the Irrua-Etsako distance relays for the transmission lines being considered. The performance metric was considered in terms of operating time at which the distance relay trips as a result of the tripping action sent from the circuit breaker to both relays.

Table 4.4: Relay 1 (R_1) performance during the three-phase fault.

Fault Type (Three-phase fault)	Relay 1 (R_1) performance		
	Fault Distance (%)	Zone Trip signal	Trip time (second)
ABC	0-19	Zone 1 start	0.50
ABC	20-39	Zone 1 start	0.40
ABC	40-59	Zone 1 Middle	0.30
ABC	60-80	Zone 1 end	0.13
ABC	81-99	Zone 2 start	0.10
ABC	100	Zone 2 end/ Zone 3	0.09

Table 4.5: Relay 2 (R_2) performance during the three-phase fault.

Fault Type (Three-phase fault)	Relay 2 (R_2) performance		
	Fault Distance (%)	Zone Trip signal	Trip time (second)
ABC	100	Zone 2	0.20
ABC	81-99	Zone 2	0.10
ABC	60-80	Zone 1	0.13
ABC	40-59	Zone 1	0.30
ABC	20-39	Zone 1	0.40
ABC	0-19	Zone 1	0.50

CONCLUSION

The distance relay performances for relays, R_1 and R_2 at fault distances (%) for the Irrua-Etsako and the Okpilla lines of the Edo side of the 132 kV transmission network was not satisfactory because it had abnormal tripping time as a result of its delayed fault clearance at the first instance of the three-phase fault. It is vital to conclude with the following findings which are as follow:

(1) For the Irrua-Etsako and the Okpilla lines, the relay 1, R_1 and the relay 2, R_2 at zone one (1) start had a delayed tripping time of 0.4 second and 0.10 second due to its un-instantaneous tripping action at 60-80% fault distances at the same zone. While, the relay 1, $R_1$and the relay 2, R_2 at zone two (2) start and zone 2 end / zone 3 had an instantaneous tripping action of a delayed tripping time of 0.4 second and 0.13 second, which had an instantaneous tripping action at 81-99% fault distances at zone two (2) end/zone 3 boundary.

(2) The tripping actions of the distance relays at the Irrua-Etsako and Okpilla lines were not instantaneous during the three-phase fault due to the slow tripping of relay 1 (R_1) and the fast tripping of relay 2 (R_2), which caused the mal-operation of the distance relays.

(3) The high fault current magnitude of 3.238 kA and 2.901 kA that flew across the faulted lines, which

were responsible for the low impedances experienced by the distance relays at the Irrua-Etsako and Okpilla lines.

The relevance of this research is that the research has investigated the performance of the distance relays at the Edo region of 132kV Transmission network and relevant findings were stated so as to further create a leeway for the improvement of the distance relay performance by harnessing other suitable methods. This could provide insight on enhancement of the distance relay settings through artificial intelligence methods.

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