Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2025, 12(4):82-90

Research Article ISSN: 2394 - 658X

Enhanced Relay Coordination in Tungbo 11kV Feeders in Sagbama Substation, Bayelsa State Nigeria

Okosi Festus, Hachimenum N. Amadi, Richeal Chinaeche Ijeoma

feskosi@gmail.com, hachimenum.amadi@ust.edu.ng, ijeoma.richeal@ust.edu.ng,
Electrical Engineering Department, Rivers State University, Nkpolu - Oroworukwo Port - Harcourt, Nigeria

ABSTRACT

Proper coordination of relays is essential to minimize unnecessary outages, since protection relay is one of the equipment in the power system that can detect any abnormal activity and protect the area under its observation. In order to reduce unnecessary outages, relays coordination must be done in a manner that a relay nearest to the point of fault operates, but in the event of failure, the backup protection does. This work introduced an improved method of relay coordination in Tungbo 2 x 15 MVA, 33/11kV (Kilo-Volts) injection substation, Bayelsa State. Short circuit analysis technique was used to determine fault current, fault MVA, while Electrical Transient Analysis Program (ETAP 19.0) was used to simulate both the existing and improved network in order to evaluate the relay coordination sequence and time of operation under fault conditions. Data used were collected from Port Harcourt Electricity Distribution Company and Transmission Company of Nigeria. The simulation results obtained show that for the existing case, when 3-phase fault was initiated at Okoloba 2 feeder, tripping sequence violation occurred revealing a total time of operation between the primary relay and its backup as 341.4ms, 423.6ms, 475.1ms and 720.5ms, with order of tripping from 33kV line breaker to 33kV control panel to T1, 11kV incomer and to Okoloba 2 feeder breaker respectively. In the improved network case, a trial and error method was used to select a suitable low voltage side Current Transformer (CT) ratio 900/5(N1 /N2) as against the existing 1200/5 Current transformer ratio to correct the mismatch between secondary currents of Current Transformer at High Voltage (HV) and Low Voltage (LV) sides, the time of operation was 60.3ms, 99.8ms, 100.1ms and 135.3ms, and it showed the right order of relay tripping coordination from Okoloba 2 feeder breaker to 11kV incomer breaker to 33kV control panel breaker and to 33kV line breaker. Similarly, for the existing case in Okoloba 1 feeder, when a three phase fault was initiated at Okoloba 1 feeder, tripping sequence violation occurred, revealing a total time of operation between the primary relay and its backup as 341.4ms, 423.6ms, 475.1ms and 720.5ms with order of tripping from 33kV line breaker to 33kV control panel to 11kV incomer and to Okoloba 1 feeder breaker respectively. When Low Voltage side, Current Transformer ratio of 900/5 was selected through trial and error method, the time of operation was 61.5ms, 99.3ms, 100.1ms, and 135.3ms and it also indicated right order of relay tripping sequence from Okoloba 1 feeder breaker to 11kV incomer breaker to 33kV control panel breaker and to 33kV line breaker. The improved cases showed correct sequence of breaker tripping 1234 orders and the speed of operation was also improved upon.

Keywords: Current Transformer Ratio, Coordination of Relays, Protection Relay, Tripping Sequence, Unnecessary Outages

INTRODUCTION

In modern era, the demand for electrical power generally is increasing at a fast rate in economically emerging countries. So the power system networks are becoming very complicated. The issue of protective relay coordination has been of great concern recently. Several studies have been conducted in relation to electric power distribution reliability and solutions have been proposed to improve the protective relay coordination. This current research is not an exception, but an addition in the development in the area of applicability. So, attempt is made to review relevant literatures on assessment and improvement of relay coordination of the power system in order to enhance the security and reliability of a power system relying on establishing and maintaining proper coordination among the protective relays.

Electrical energy is the basic necessity for the economic development of a country due to its importance to human life and occupies the top position in the energy hierarchy. It finds innumerable uses in the home, industry, agriculture, and transport. The demand for electrical power is generally in the increase at a fast rate in economically developing countries like Nigeria. So, the power distribution networks are becoming highly loaded; so, the issue of protection scheme has become a great concern in most of the injection substation power distribution networks. A number of works have been carried out in the area of electric power distribution protection and solutions have been proposed to improve the protection of the distribution network (Ijeoma and Amadi, 2024).

In power system, all the generated energy is consumed by the end users through the distribution system which is the last stage in electric power delivery, and it feeds the electricity demand of all the consumers (Olajuyin, Olulope and Fasina, 2022). So, it is a vital part of the electric power system, since it delivers electricity from the power plant to the end users. The power performance or reliability of a power system network is associated with outages, interruptions failure, unavailability and these problems are closely associated with power system protection and control. Transmission and distribution sections protection play important role in maintaining the quality and reliability of the power systems, which are often subjected to disturbances.

In developing countries like Nigeria, there is an increase in population and technological advancement; there is also a corresponding increase in demand of electrical energy with attendant operations of the power system close to its limit. The setting and coordination of protective relays have become very a complex and tedious task. Especially in the study area (Tungbo Feeders) which over the year has been experiencing mal-operation, instantaneous tripping, cascaded tripping and unnecessary outage due to improper relay coordination. This reason arouse the interest forth is study to carry out relay coordination analysis of the study case power system and proposes an efficient and properly coordinated over-current protection system by proposing the application of modern differential relays who have in built external interposing current transformers (ICTs) software to select appropriate CTRs ratios among current transformers in the study case network in order to improve the speed of operation and maintain the right operation sequence (Amadi et al., 2024).

It cannot be over emphasized that a reliable and efficient power supply is a panacea to socio-economic growth and productivity. Electricity is an essential requirement for all areas of human endeavor; it plays an important role in the economy of any nation. So, there is need for an increase in the quality and quantity of power supply in order to cater for the load requirement and create a competitive advantage for any country (Airoboman, Oluseyi, Udoakam and Babatunde, 2022; Amuta, Wara, Agbetuyi and Matthew, 2018). The basic function of a power system is to supply all consumers (Domestic, Commercial and Industrial) with electrical energy as economically as possible with an acceptable degree of reliability and quality (Andrea, Armando, Jorge and Jao, 2022).

Jaishree and Thangalakshmi (2016) carried out a study on the planning and coordination of relay in distribution system. The distribution network of Surana industries was considered for analysis. ETAP was used as a simulation tool for the proper operation of back up relays to decide the quality protection in distribution network. The fault conditions and the protection coordination problem are formulated and simulated in ETAP. The use of Fault Current Limiters (FCL) and the design of Coordination Time Interval (CTI) are also considered. The fault condition is simulated in the test system and relays used in the system were coordinated with insertion and removal of DG units.

Idoniboyeobu et al. (2018) proposed a study on improved protection for Rivers State University 2X15MVA 33/11KV injection substation. The data used for the research were received from Port Harcourt Electricity Distribution Company (PHEDC) and were calculated using hand calculation. Electrical Transient Analysis Program (ETAP) software was used for verification of protective relay sensitivity. The results obtained show that lightning arresters and protective discharge current was 0.7996KA meaning that the available 5KA lighting arresters in use are adequate and protective margin of 145% is adequate as it is >20%. Contrarily, transformer protection of the existing case shows a matching CT of ratio 3.280A/4.374A which is mismatch, but when an improved CT ratio is proposed, it shows a CT ratio of 4.921/4.374A. The sequence of relays operations was also improved.

Obied and Abdul-Wahhab (2021) carried out study on protection coordination of 33/11kv power distribution substation in Iraq. The aim of the work is to coordinate the protection of 33/11kv power distribution substation in Iraq using CYME 7.1 software package. In their work, overcurrent and earth fault relays were simulated in two cases, with time delay setting and instantaneous setting, to obtain the Time current Characteristics (TCC) curves for each circuit Breaker (CB) relay of Al-karama substation (2x31.5MVA, 33/11KV) in Babil distribution network. The results obtained show TMS of 0.1 sec for the relay of CB 33KV feeder Al-Karama-2, which is adjudged very low, while it showed be TMS = 0.322 according to calculation done, so as to achieve coordination with Karama substation. They concluded that Hukam feeder is overloaded and it works with load current almost twice the CT size. The current should not exceeds 1.2 of the CI size continuously to avoid over saturation, they propose changing the CT size to 600:1 instead of 300:1 for Hukam feeder as a quick solution.

Suhardi et al. (2022) presented a paper on coordination analysis of protection relays settings utilizing particle Swarm Optimization Method in Cempaka substation which is one of the existing electricity distribution system in South Kalimantan was used as a case study. The aim of their study is to navigate the valve of the relay setting, optimization method applied is particle Swarm Optimization (PSO) to produce optimal values for relay settings. The calculation is conducted with the help of MATLAB software. The calculation results of time dial setting (TDS) and the value of the pickup current (IP) was entered into ETAP software for simulation when a disturbance occurs. The results obtained show that the time between primary relay and backup was 1.2 seconds which is close to 0.3 seconds which acceptable international standard.

Reliable energy technologies are expected to play a major role in mitigating pressing societal challenges such as climate change and resource depletion, while contributing to domestic energy security. Just as no human being can survive without the flow of blood, no nation or city can develop without reliable electricity. (Ibinabo and Ijeoma, 2019).

Horsfall et al. (2021) carried out a research on relay coordination analysis in SPDC Forcados distribution network for operation, planning and future expansion. They performed load flow study and short circuit current analysis for proper selectivity. This analyses formed basis for optimal setting of overcurrent Relays (OCRs) via standard Inverse Time delay (SIT). Electrical Transient Analysis Program (ETAP) software was used for the simulation. The result obtained show that the existing definite time delay with current time grading amounted to higher relay current-time configuration at the upstream in the steps of 0.5s up to a minimum time of 3s and with steps of 25%, the upstream at this setting experienced thermal overload. But the propose Standard Inverse Time (SIT) resolved the inadequate relay definite time characteristics setting resulting to thermal overload (I2R) of the 25MVA and incessant tripping. The SIT also accommodates the associated circuit breakers response breaking capacity time (380ms to 500ms) which better compares the existing definite inverse characteristics.

Godwal et al., (2023) proposed a study on design and analysis of power distribution system for optimum over-current relay coordination using voltage component of fault current limiters. A prototype of the ring mains distribution system was developed to evaluate the effectiveness of the reported characteristics and proposed objective function. The reported characteristics and proposed objective function were tested on a 9-bus distribution system.

From the review of existing literatures until this research was proposed, there are some issues that has not been covered about a large number of relay tripping and miss-coordination in power system due to inappropriate/inadequate settings. Some of the researchers (Obied and Abdul-Wahhab, 2021); Suhardi, Pakaya, Putri and Faruq, 2022) propose the use analytical and heuristic methods for optimization of relay setting in power system. Analytical method has the shortcoming of inaccuracy of solution, while heuristic method requires quality data and takes larger space in computer memory. This create gap of coming up with a suitable strategy approach for improved relay setting. In the study area power system, the relaying operation is electro-mechanical (relay type). This study intends to introduce an electromagnetic system (relay type) which has inbuilt capacity to be digitally (automatically) operated to select the appropriate current transformer ratios (CTR) at the low voltage (LV) side of the current transformer in order to correct the miss-match between the secondary current of CT at HV and LV sides thereby improving the relays coordination to have a reliable outcome with a specific objectives:

i. To carryout short circuit analysis calculations of the study case network using time and plug settings of the existing over-current relays in the network.

ii. To model and simulate the existing study area network for relay coordination studies using ETAP software in order to determine, the relays time of operation and sequence of operations when Tungbo Feeder is subjected to a 3 phase fault.

iii. To replace the existing low voltage side CT ratio with an appropriate value using trial and error method, then run relay coordination simulation again.

MATERIALS AND METHOD

Research Materials Used

The material used in this research includes the following:

i. The single line diagram of the study case network.

ii. The bus and line data of the network (Resistance, reactance, cross-sectional area of the conductor, load and route length of the line) and the existing relay setting information of the network received from TCN and PHED.

iii. Electrical Transient Analysis Program (ETAP 19.0) Software

iv. Excel Microsoft Software packages

Research Method Used

In this study, methods employed are analysis and simulation. Load flow studies were performed on the study case network in order to determine the existing network parameter like voltage magnitude, power flow. Short circuit analysis was carried by using hand calculation, and then uses the result with the existing case relay setting information to carry out relay coordination simulation studies of the network on ETAP when a three phase short circuit faulted is initiated at 11kV feeder.

Improving on the relay coordination by proposing the application of digital relay which has an inbuilt mechanism to set the appropriate current transformer ratio, and then perform relay coordination simulation studies again.

Table 1: Data Used for Calculation and Simulation

S/N	Parameter	Assigned Value
1	Route length of 33kV line	5.2km
2	Maximum load on 33kV line	11.70MW
3	T_1 30MVA impedance at Transmission station	12.6%
4	T_2 15MVA impedance of injection substation	10.62%
5	T_3 15MVA impedance at injection substation	10.53%
6	Peak Load on Okoloba 2 11kV Feeder	3.4MW
7	Peak load on Okoloba 1 11kV Feeder	4.2MW
8	Peak load on Tungbo 11kV Feeder	3.2MW
9	Peak load on Ayamabiri 11kV Feeder	3.8MW
10	Conductor size for 11kV line	150mm.sq
11	Conductor size for 33kV line	240mm.sq
12	Conductor Type	AAC
13	Base MVA	100
14	Relay Types	LGT O/C & EF relay (MC 31A). GE Multilin O/C & EF relay (DIAC/DIFC/DSFC)
15	Conductor Resistivity at 20°C	2.65 x 10^{-8} Ωm
16	33kV line spacing	3ft = 914.4mm
17	Incomer CTRs, 33kV	300/5
18	Outgoing CTRs, 11kV	1200/5

Source: Transmission Company of Nigeria & Port Harcourt Electricity Distribution Company (2023)

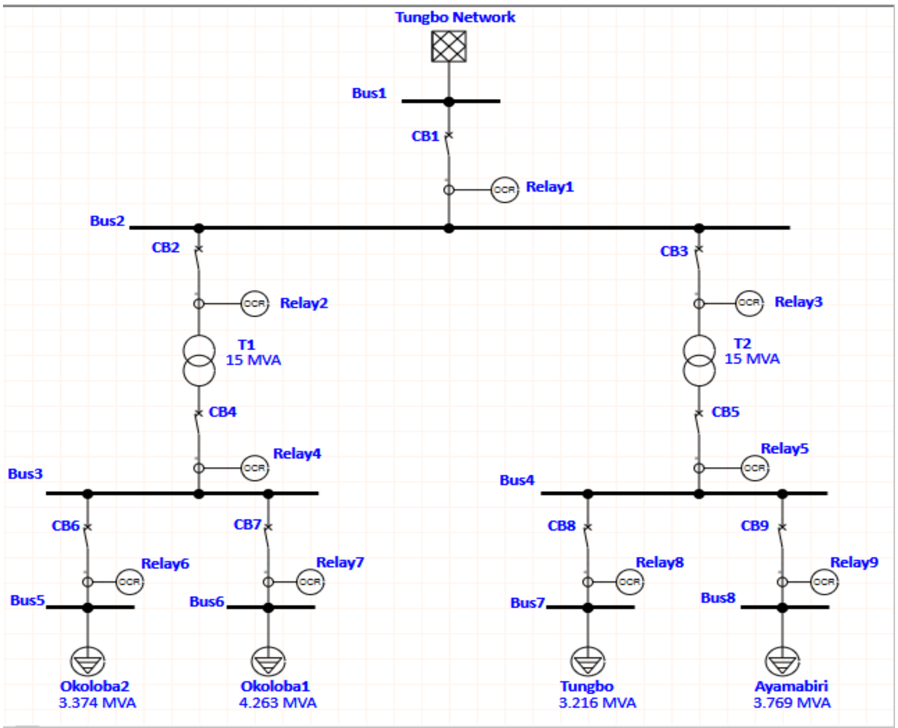

Figure 1: Single Line Diagram of the Study Case Network

Short Circuit Modeling, Simulation and Analysis of the Study Case Network

Short circuit analysis was used for determining short circuit impedance, short circuit current, circuit breaker breaking and marking capacity. All components on the network such as supply grid, transformer, line, and generators are characterized by impedance (Z). The short circuit impedance value of the grid network and transformers upstream from the point of fault are determined below using impedance method.

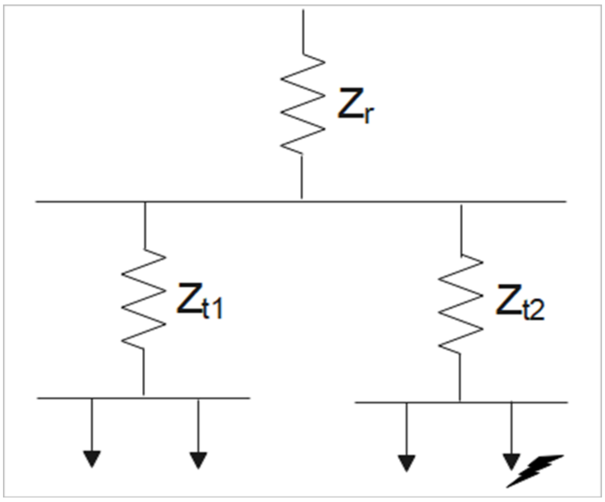

Figure 2: Equivalent Circuit of the Distribution System

Determination of Short Circuit Impedance of the Grid Network

If a DC current is flowing around a cylindrical conductor, the DC resistance of the conductor is determined using equation (1)

$$R = \frac{\rho l}{A} (\Omega) \quad (1)$$

Where;
R: Resistance of the conductor in Ω
l: Length of the conductor = 5.2km
A: Cross-sectional area of the conductor = 150mm^2
ρ: Resistivity of the conductor at $20°\text{C} = 2.65 \times 10^{-8} \Omega m$
The cross sectional area of a conductor is determined using equation (2)

$$A = \frac{\pi d^2}{4} \quad (2)$$

Where
A: Cross sectional area of the conductor
d: Conductor diameter
The per kilometer reactance of one phase of the line can be evaluated using equation (3).

$$X_o = 0.1445\ log_{10}\left(\frac{DGMD}{r}\right) + 0.0157 \quad (3)$$

Where;
From table 1
X_o: Per kilometer reactance of one phase
$DGMD$: Geometric mean distance between the line conductors = 914.4mm
r: Radius of the conductor
$X_o = 0.1445\ log_{10}\left(\frac{914.4mm}{6.91mm}\right) + 0.0157 = 0.3223\Omega/km$
The line reactance, X can be calculated using equation 4

$$X = X_o l_o \quad (4)$$

Where;
From table 1,
X: Line of reactance in Ω
X_o: Per kilometer reactance of one phase of the line
l_o: Route length of the line = 5.2km
$X = 0.3223 \times 5.2 = 1.676\Omega$
Distributed series impedance is now evaluated as given in equation (5)

$$Z_i = R + jX \quad (5)$$

Where;
R: Conductor resistance in Ω
X: Line reactance in Ω
$Z_i = 0.919 + j1.676\Omega = 1.9114\angle 61.26°$

Determination of Source Impedance in Per Unit

As shown in table 1, base MVA is chosen to be 100, source impedance is 12.6%. source impedance in p.u can be determined by using equation (6)

$$Source\ impedance = \frac{Z\% \times Base\ MVA}{Transformer\ MVA} \tag{6}$$

Determination of Series Distributed Impedance in per Unit

The series distributed impedance can be evaluated in per unit by using equation (7)

$$Z_1\ p.u = \frac{Z_1 \times Base\ MVA}{(V)^2} \tag{7}$$

Where,
Z_1: Distributed series impedance
V: 33kV incomer voltage

Determination of Fault Impedance at Transformers T1 and T2

The transformer T1 and T2 base MVA is chosen to be 100
To determine the per unit fault impedance at transformer T1 and T2 at Tungbo injection substation, equation (8) will be applied,

$$Z_T\ p.u = \frac{Z_T\% \times Base\ MVA}{Transformer\ MVA} \tag{8}$$

Where;
$Z_T\ p.u$: Fault impedance in p.u
$Z_T\ \%$: Percentage impedance

Determination of Total Fault Impedance on Transformers T1 and T2 at Tungbo Injection Substation

The total fault impedance on transformer T1 can now be evaluated as given by equation (9)

$$ZF_{T1} = Zs + Z_1 + ZT_1 \tag{9}$$

$ZF_{T1} = 0.42 + 0.1755 + 0.708$
$ZF_{T1} = 1.3035\ p.u$

Similarly, total fault impedance on transformer T_2 can be determined by using equation (10)

$$ZF_{T2} = Zs + Z_1 + ZT_2 \tag{10}$$

Determination of Fault MVA on Transformers T_1 and T_2

The fault MVA on transformers T_1 and T_2 at Tungbo can be evaluated using equation (11).

$$Fault\ MVA = \frac{Base\ MVA}{Total\ Fault\ Impedance\ on\ the\ transformer} \tag{11}$$

For Transformer, T1,
$Fault\ MVA = \frac{Base\ MVA}{ZF_{T1}}$
For Transformer, T_2

Determination of Fault Current on Transformers T_1 and T_2

The fault current on transformers T_1 and T_2 can be determined by using equation (12)

$$Fault\ Current = \frac{Fault\ MVA}{\sqrt{3} \times V_{SL}} \tag{12}$$

RESULTS AND DISCUSSION

The existing case and the improved case of relay coordination simulation results of the study case network, when a three phase short circuit fault is initiated at both 11kV Okoloba 2 and Okoloba 1 feeders, were captured with reference to relays tripping sequence and relays time of operation as well as circuit breakers time of operation.

Result and Discussion of Simulation Diagram of Base Case for Fault on Okoloba 2 Feeder

Figure 3 shows the order of tripping sequence of primary relay and backup relays when a 3-phase fault was initiated at Okoloba 2 feeder (Bus 5) and simulated in the base case scenario. when a three phase fault is initiated at Okoloba 2 feeder(Bus 5) it is observed that the tripping sequence is in the order of Relay 1 to Relay 2 to Relay 4 to Relay 6 (primary relay at the point of fault) at a time of response of 341.4ms, 423.6ms, 475.1ms and 720.5ms respectively, this indicates that the relays responses is wrong and violated the right order of relay operation/coordination which supposed to be from Relay 6 (primary relay at the point of fault) to Relay 4 (backup) to Relay 2 to Relay 1.

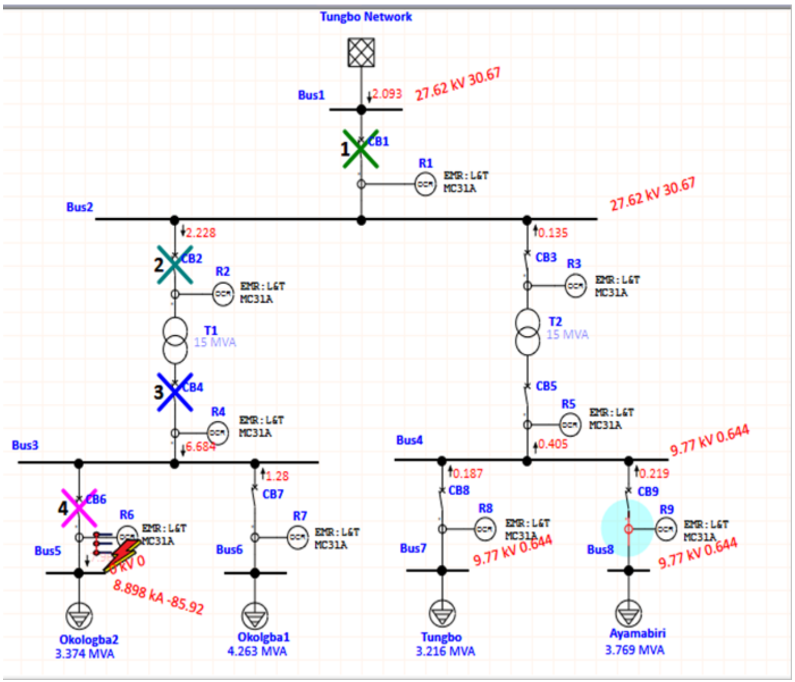

Figure 3: Simulation Diagram of Base Case for Fault on Okoloba 2 Feeder

Result and Discussion of Simulation Diagram of Base Case for Fault on Okoloba 1 Feeder

This result clearly shows the order of tripping sequence of primary relay and backup relays when a 3-phase fault was initiated at Okoloba 1, feeder (Bus 6) and simulated in the existing case scenario. From the simulation result as shown in figure 3, when a three phase fault is initiated at Okoloba 1feeder(Bus 6) it is observed that the tripping sequence is in the order of Relay 1 to Relay 2 to Relay 4 to Relay 7 (primary relay at the point of fault) at a time of response of 341.4ms,423.6ms,475.1ms and 720.5ms respectively. This indicates that the relays responses is wrong and violated the right order of relay operation/coordination which supposed to be from Relay 7(primary relay at the point of fault) to Relay 4 (backup) to Relay 2 to Relay 1.

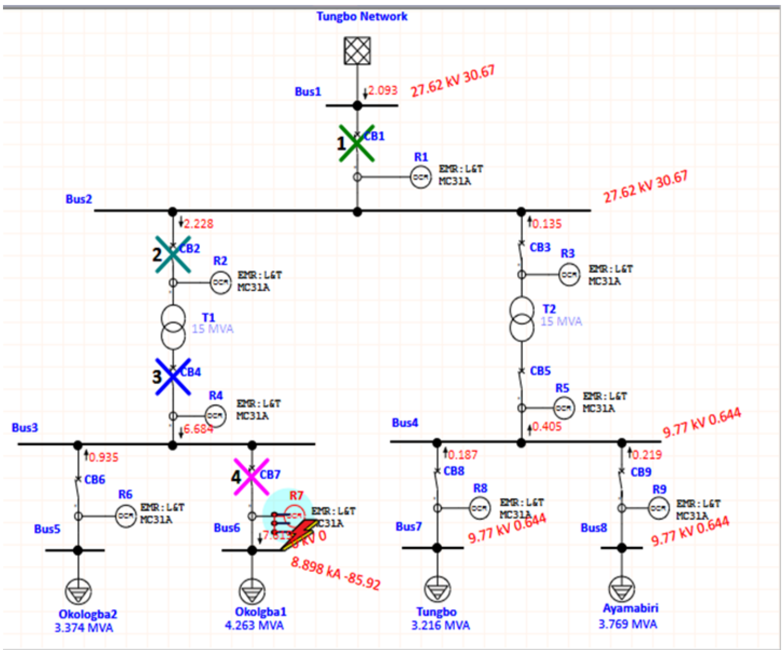

Figure 4: Simulation Diagram of Base Case for Fault on Okoloba 1 Feeder

Result and Discussion of Simulation Diagram of Improved Case for Fault on Okoloba 2 Feeder

This shows the order of tripping sequence of primary relay and backup relays when Okoloba 2 feeder (Bus 5) was subjected to a 3-phase fault and simulated in the improved case scenario. From the simulation result as shown in figure 5, when a three phase fault is initiated at Okoloba 2 feeder (bus 5) it is observed that the tripping sequence is in the right order of Relay 6(primary relay at point of fault) to Relay 4 (backup relay) to Relay 2(next backup relay) to Relay 1(last backup relay) at a time of 60.3ms, 99.8ms, 100.1ms and 135.3ms respectively. The mode of operation indicates proper relay coordination and right tripping sequence to the circuit breakers.

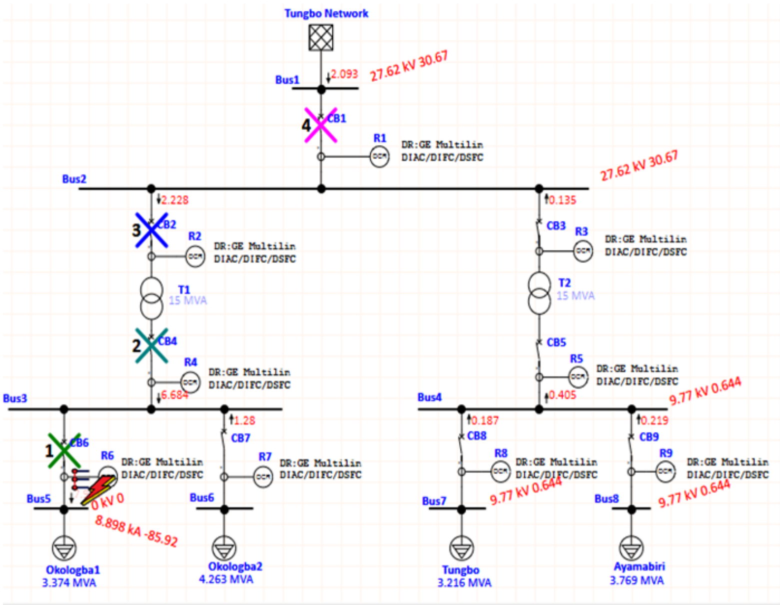

Figure 5: Simulation Diagram of Improved Case for Fault on Okoloba 2 Feeder

Result and Discussion of Simulation Diagram of Improved Case for Fault on Okoloba 1 Feeder

Figure 6 shows the tripping sequence of primary relay and backup relays when Okoloba 1 feeder (Bus 6) was subjected to a 3phase fault and simulated in the improved case scenario. the simulation result as show that when a three phase fault is initiated at Okoloba 1 feeder (bus 6) it is observed that the tripping sequence is in the right order of Relay 7 (primary relay at point of fault) to Relay 4(backup relay) to Relay 2 (next backup relay) to Relay 1(last backup relay) at a time of 60.3ms, 99.8ms, 100.1ms and 135.3ms respectively. The mode of operation indicates proper relay coordination and right tripping sequence to the circuit breakers. The Time Current Curves for the improved case

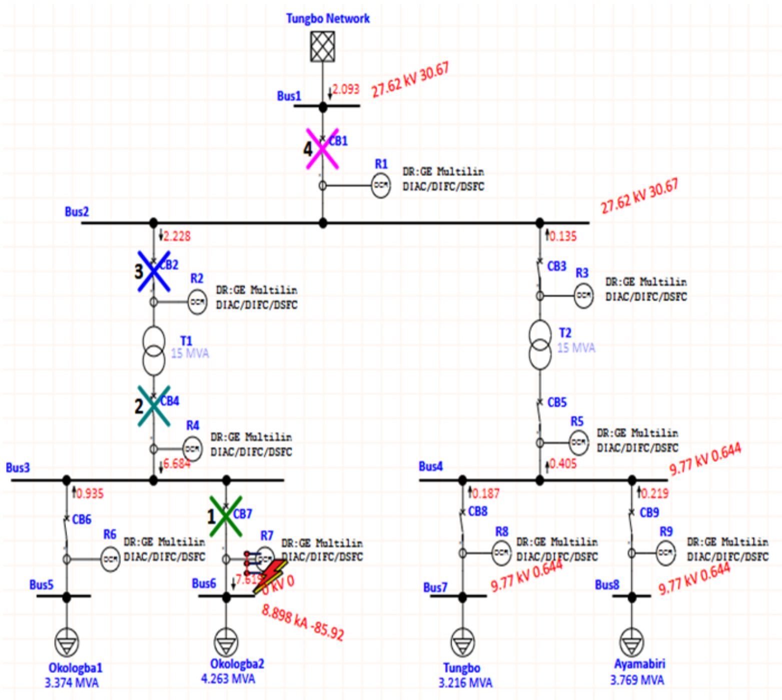

Figure 6: Simulation Diagram of Improved Case for Fault on Okoloba 1 Feeder

CONCLUSION

Unreliable and inefficient power system due to improper coordination of the protective device is one of the major problems encountered on daily basis by the power system operators. Proper protective device coordination is a priority for reliable electricity supply, it minimizes downtimes and guarantees the safety of personnel. This research work investigates the relay coordination and its improvement on Tungbo 11kV feeders in Sagbama substation, Bayelsa State. The data used for analysis and simulation was collected from Transmission Company of Nigeria (TCN) and Port Harcourt Electricity Distribution Company (PHED). The existing study area network was modelled and simulated using Electrical Transient Analyzer program (ETAP) software. Methods used were straight forward, short circuit analysis was carried out on 33/11kV Tungbo feeders in Bayelsa State, in order to determine the system fault current and fault MVA. The existing test case network was modelled in ETAP (19.0) software for relay coordination studies, and all results obtained were recorded. At the instance of initiating a 3-phase fault at 11kV Okoloba 2 feeder and 11kV Okoloba 1 feeder, the simulations result obtained show that there is a miscoordination of protective devices in response to fault conditions, and the tripping sequences was inappropriate for faults on Okoloba 2 and Okoloba 1 feeders. In the improved case, when a suitable current transformation ratio was chosen using trial and method, at the instance of initiating a 3-phase fault at Okoloba 1 and Okoloba 2 feeders, the simulation results obtained show that the right order of tripping has now be maintained. The tripping order is now from 11kV feeder circuit breaker to 11kV incomer to 33kV control panel and then to 33kV line incomer. It implies the appropriate tripping sequence 1, 2, 3 and 4 has now been maintained as against existing case of 4,3,2,1 orders.

REFERENCES

[1]. Airoboman, A. E., Salau, A. O. & Chhabva, M. (2022) Review of the performance of the power sector in some selected African Countries. IEEE Nigerian 4th International Conference, 17th – 19th May, Nile University, Abuja, 1-5

[2]. Amadi, H.N., Okosi F., & Ijeoma, R.C. (2024) Simulation and Analysis of Improved Relay Coordination in Tungbo 11kV Feeders in Sagbama Substation, Bayelsa State, Nigeria. European Journal of Advances in Engineering and Technology, 11(11): 41-49.

[3]. Amuta, E., Wara, S., Agbetuyi, F. A. & Matthew, S. (2018) Smart grid technology potential in Nigeria: An Overview; International Journal of Applied Engineering Research, 13(2), 91-100

[4]. Andrea, M. R., Armando, M. L. S., Jorge, L. J. & Jao, C. M. (2022) Static and dynamic aspects in bulk power system reliability evaluations, IEEE Trans. Power System, 15(1), 189-195

[5]. Fubara, I., & Ijeoma, R.C. (2019) Investigating the Reliability and Viability of Embedded Generation to Improve the Power Supply (Eleme, Rivers State as a Case Study), IOSR Journal of Engineering (IOSRJEN), 09(08) 27-37

[6]. Godwal, S. D., Pandya, K. S., Nimje, A. A., & Rajput, V. N. (2023) Design and analysis of power distribution systems for optimum over-current relay coordination using voltage component of fault current International Journal of Advanced Technology and Engineering Exploration limiters. 10(102), 624-640

[7]. Horsfall, D. J., Idonibuoyeobu, D. C., Ahiakwo, C. O. & Braide, S. L. (2021) Relay coordination analysis in SPDC Forcados distribution network for operation, planning and future expansion. Journal of Newviews in Engineering and Technology (JNET), 3(4), 18-27

[8]. Idoniboyeobu, D. C., Braide, S. L., Ekeriance, D. E. (2018) Improved protection for Rivers State University 2X15MVA, 33/11KV injection substation. America Journal of engineering Research (AJER), 7(8), 62-74

[9]. Ijeoma, R.C., & Amadi, H.N. (2024) Analysis of a Grid-Based Rural Electrification Scheme for Ekpe-Aggah Community in Rivers State, Nigeria. International journal of Engineering and Modern Technology (IJEMT), 10(6), 148-158

[10]. Jaishree, J. & Thangalakshmi, S. (2016) Planning and Coordination of relay in distribution system. International Journal of Emerging Technology in Computer Science and Electronics (IJETCSE), 22(3), 154-162

[11]. Obied, Y. M. & Abdul-Wahhab, T. M. (2021). Protection coordination of 33/11kv power distribution substation in Iraq. Engineering and Technology Journal, 39(5), 723-737

[12]. Olajuyin, E. A., Olulope, P. & Fasina, E. T. (2022) An overview on reliability assessment in power systems using CTI approaches. Archives of Electrical Engineering, 71(2), 425-443

[13]. Suhardi, D., Pakaya, I., Putri, R. & Faruq, M. (2022). Coordination analysis of protection relay setting utilizing particle swarm optimization method. AIP conference Proceedings, 2453 (1), 1-5.