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Analysis of Akangba Transmission Substation Protection System

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Abstract

The challenges of the Nigeria power system have deprived the yearning electricity consumer access to stable power supply. Apart from the incessant load shedding due to inadequate power generation capacities, poor power system protection design, lack of constant protection system review after several changes to the power network is one of the contributing factors for unstable power system and unplanned outages. The network engineers must devise method of reviewing the protection settings as changes are made to power system components. This motivates the adoption of power system symmetrical fault analysis model presented herein. The model was applied to Akangba Transmission substation using the network planning software (NEPLAN software). The results show the fault current flowing through every part of the network. The effect of network expansion, switching Scenarios /Component changes on the fault current and protection scheme was also verified. Protection engineers must therefore take note of changes in the power network configuration when planning protection coordination and relay setting. The method is interesting and can be used as a template for reviewing protection scheme when changes are made on the power network. This will ensure better power protection management, enhance stable power supply and reduce damage to expensive power components.

Keywords: Protection system review, unplanned outage, Changes made on power system component, symmetrical fault analysis, Akangba Transmission substation, Neplan software.

1.0 INTRODUCTION

The power system has evolved over time. Generation plants, transmission facilities, distribution lines, and customer loads are all connected through complex electrical networks. Due to this complexity, adequate protection has become paramount to ensure security and quality of power supply. The primary function of any power system protection is to prevent or limit damage to power system components. Whether the fault or abnormal condition exposes the equipment to excessive voltages or excessive currents, shorter fault times will limit the amount of stress or damage that occurs [1].

Power systems are not static networks. Transmission lines and generators are continuously being put into or taken out of service. Each change in the network potentially affects the operations of protective relays. Protection engineers must decide how to alter the relay settings to compensate for a change in the power network [2].

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The demand for power has increased rapidly with advancement in technology. This has also brought about urgent need for expansion of power network and replacement of existing power system components. Implementation of those changes must be such that it does not upset the balance of power supply [3]. The aim of this paper is to investigate the effect of this constant changes and switching configuration on the protection settings of a power network. The first step to achieving the aim was to create a simulation platform which allows the Akangba power network to be analyzed on power analysis software.

This is to ensure planned changes are simulated to determine the fault current and required relay settings for the changes made on the network. The paper is also meant to be used to encourage the aggregation of the Nigeria power network centrally with a power analysis software to monitor and control changes on the entire network. This will ensure efficient network planning and prevention of damage caused by improper relay setting due to various power component modifications across the network. Other relevant research was also considered. Author [4] used mathematical formation of Admittance matrices and computational framework of short circuit analysis program (SCAP) to assess the composite effects of balanced and unbalanced faults on the overall reliability of electric power system using a 6-bus power system. The result is outstanding but has limitation when extending it to complex network due to the triangular admittance matrices formation and factorization.

[5] adopted Electrical Transient and Analysis program (ETAP) to evaluate the transient stability limits of Ikeja west Sub-network with consideration for transmission line faults and result showed the power station that could cause serious loss of synchronism during fault conditions based on the present load.

Author [6] used his research to highlight ways of solving the planning issues associated with electric power distribution networks that is important for designers and investors to help optimize network cost plan. The Mixed binary linear programming (MBLIP) modelling was used to achieve excellent computation and robust solution.

Author [7] assessed the effect of introducing additional power source (i.e., Distributed generator) on the protection scheme of 33kv radial network. It highlighted how most protective device coordination fails due to changes in power flow, direction, and the magnitude of fault current contribution from the additional generators on the network. The paper used Simulink modelling and programmable FCL to make the protection schemes more extensible to allow future addition of DGs without modifications to existing scheme.

Author [8] presented the state of specific load centers connected on the 330kVA transmission network under fault using Etap software for analysis.

In this paper, the Akangba Transmission substation protection system was analyzed and investigated to verify the effect of the newly acquired, installed and yet to be commissioned 300MVA transformer on the protection scheme. This was tested by opening and closing the 300MVA transformer breaker and simulating fault for each scenario. This was to confirm the level of changes in the fault current when expansion, modification is made to the network. The Akangba Transmission Substation was considered because it's a hub for 132kV lines (Isolo, Itire, Ijora, Ojo) and 33kV lines (Iganmu, Amuwo, Sanya, Idiaraba, Adelabu). The entire Akangba transmission substation was modeled and simulated on the NEPLAN software. The NEPLAN is a real time planning, modeling and analysis tool with special features to perform load flow, short circuit, transient, reliability in on-load and off-load conditions. At the end of this study, fault current flowing through every part of the network was determined, thus supplying the relevant information on the protection scheme and the significant effect of the changes that the protection engineers need to ensure reliable power supply and reduce damage to expensive power components.

There are two types of faults which can occur on any transmission line: balanced fault and unbalanced fault. They are also known as symmetrical and asymmetrical faults respectively. Most of the faults that occur on power systems are the unbalanced faults. In addition, faults can be categorized as the shunt faults, series faults and simultaneous faults. In the analysis of power system under fault conditions, it is necessary to make a distinction between the types of fault to ensure the best results possible in the analysis. However, for this paper, only shunt faults are analyzed.

2.0 MATERIALS AND METHODS

2.1 Mathematical Techniques

A general representation of a balanced three-phase fault is shown in Figure 1 where F is the fault point with impedances Z_f and Z_g. Figure 2 shows the sequence networks interconnection diagram.

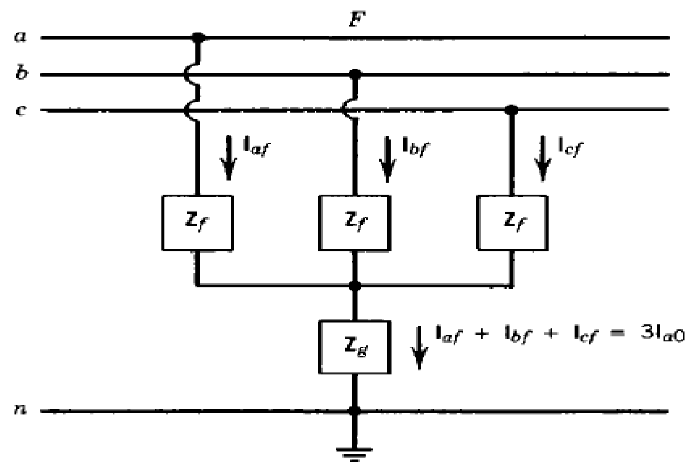


Figure 1: Three-phase fault general representation

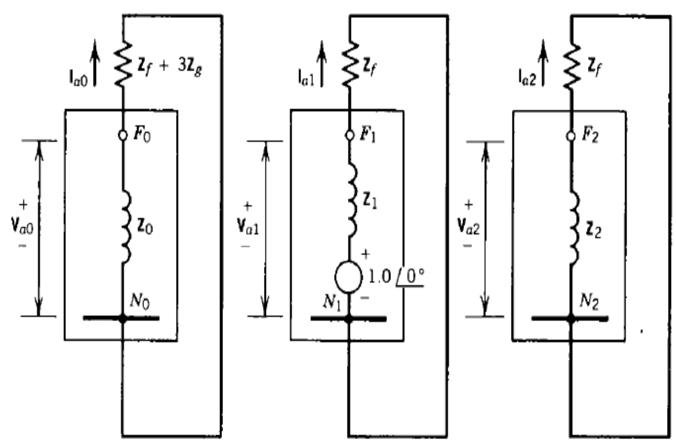


Figure 2: Three-phase fault interconnection of sequence networks

As seen from Figure 2, the positive sequence network has internal voltage source. Therefore, the corresponding currents for each of the sequences can be expressed as

$I_{a0} = 0$ (1)

$I_{a2} = 0$ (2)

$I_{a1} = \frac{1.0<0^{\circ}}{Z_1 + Z_f}$ (3)

If the fault impedance Z_f is zero, then

$I_{a1} = \frac{1.0<0^{\circ}}{Z_1}$ (4)

Since

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \quad (5)$$

Substituting equations 1 and 2 into equation 5, gives

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ I_{a1} \\ 0 \end{bmatrix} \quad (6)$$

From which,

$I_{af} = I_{a1} = \frac{1.0<0^{\circ}}{Z_1 + Z_f}$ (7)

$I_{bf} = a^2 I_{a1} = \frac{1.0<240^{\circ}}{Z_1 + Z_f}$ (8)

$I_{cf} = a I_{a1} = \frac{1.0<120^{\circ}}{Z_1 + Z_f}$ (9)

Since the sequence networks are short-circuited over their own fault impedance, then

$V_{a0} = 0$ (10)

$V_{a1} = Z_f I_{a1}$ (11)

$V_{a2} = 0$ (12)

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \quad (13)$$

Therefore, substituting equations 10, 11 and 12 into equation 13 gives

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ V_{a1} \\ 0 \end{bmatrix} \quad (14)$$

Thus,

$V_{af} = V_{a1} = Z_f I_{a1}$ (15)

$V_{bf} = a^2 I_{a1} = Z_f I_{a1} \angle 240^{\circ}$ (16)

$V_{cf} = a I_{a1} = Z_f I_{a1} \angle 120^{\circ}$ (17)

Hence, the line-to-line voltages become

$V_{ab} = V_{af} - V_{bf} = V_{a1}(1 - a^2) = \sqrt{3} Z_f I_{a1} \angle 30^{\circ}$ (18)

$V_{bc} = V_{bf} - V_{cf} = V_{a1}(a^2 - a) = \sqrt{3} Z_f I_{a1} \angle -90^{\circ}$ (19)

$V_{ca} = V_{cf} - V_{af} = V_{a1}(a - 1) = \sqrt{3} Z_f I_{a1} \angle 150^{\circ}$ (20)

In the event of having $Z_f = 0$, then

$I_{af} = \frac{1.0\angle 0^{\circ}}{Z_1}$ (21)

$I_{bf} = \frac{1.0\angle 240^{\circ}}{Z_1}$ (22)

$I_{cf} = \frac{1.0\angle 120^{\circ}}{Z_1}$ (23)

The phase voltages become

$V_{af} = 0$ (24)

$V_{bf} = 0$ (25)

$V_{cf} = 0$ (26)

And the line voltages become

$V_{a0} = 0$ (27)

$V_{a1} = 0$ (28)

$V_{a2} = 0$ (29)

2.2 Material Collection and Preparation of Samples

Akangba Transmission station located at Adelabu Street in Surulere Lagos is strategically located to interconnect power at 132kV and 33kV level to area and regions such as Amuwo, Sanya, Iganmu, Ijora, Itire, Ikeja West etc. It takes 330kV supply via Ikeja west, steps it down to 132kV via the two 150MVA, four 90MVA and the newly installed 300MVA transformers. The 132kV common bus also has 60MVA transformers that step down to 33kV.

The Akangba power network has three substation 330kV, 132kV and 33kV which are interconnected but managed by different personnel at three different substations in the same premises. The whole network has been considered as an entity in this analysis with data obtained for the different substations. The data are as listed in the appedices. For instance Appendix A gives information on line impedances, Appendix B displayed the load profile while Appendix C gives the transformer asset inventory. In the case of Appendix D it presents data of the Grounding transformers installed in the system. While Appedix E gives parameters of the installed transformers. Appendix E, Appendix F and Appendix H give information of protection schemes (I.e. relay, 330kV, 132kV breakers as well asd the 33kV breakers. The 132kV and 33kV lines connected to the Akangba Transmission Substation are named accordingly as;

I. Itire Line 1(132kV)
II. Itire Line 2 (132kV)
III. Ojo Line 1 (132kV)
IV. Ojo Line 2 (132kV)
V. Ijora Line 1 (132kV)
VI. Ijora Line 2 (132kV)
VII. Isolo Line 1 (132kV)
VIII. Isolo Line 2 (132kV)
IX. Sanya Line (33kV)
X. Amuwo Line (33kV)
XI. Igamu Line (33kV)
XII. Idiaraba Line (33kV)
XIII. Adelabu Line (33kV)

2.3 *Method of Analysis*

The single line diagram of Akangba Transmission Substation system simulated on NEPLAN is shown in Figures 3, 4 & 5. The load and transformer parameters gathered from Akangba Substation can be seen in the appendix section. The parameters were inputted into the single line diagram implemented with the NEPLAN Software. Three phase fault was simulated for different nodes to determine the fault current when the fault level at the 330kV incoming bus from Ikeja west is 1500MVA. Figure 3, 4 & 5 is a continuous network and simulated as a whole network. Twenty-seven faulted node were used as test for this simulation to model the relay positions on the present Akangba network

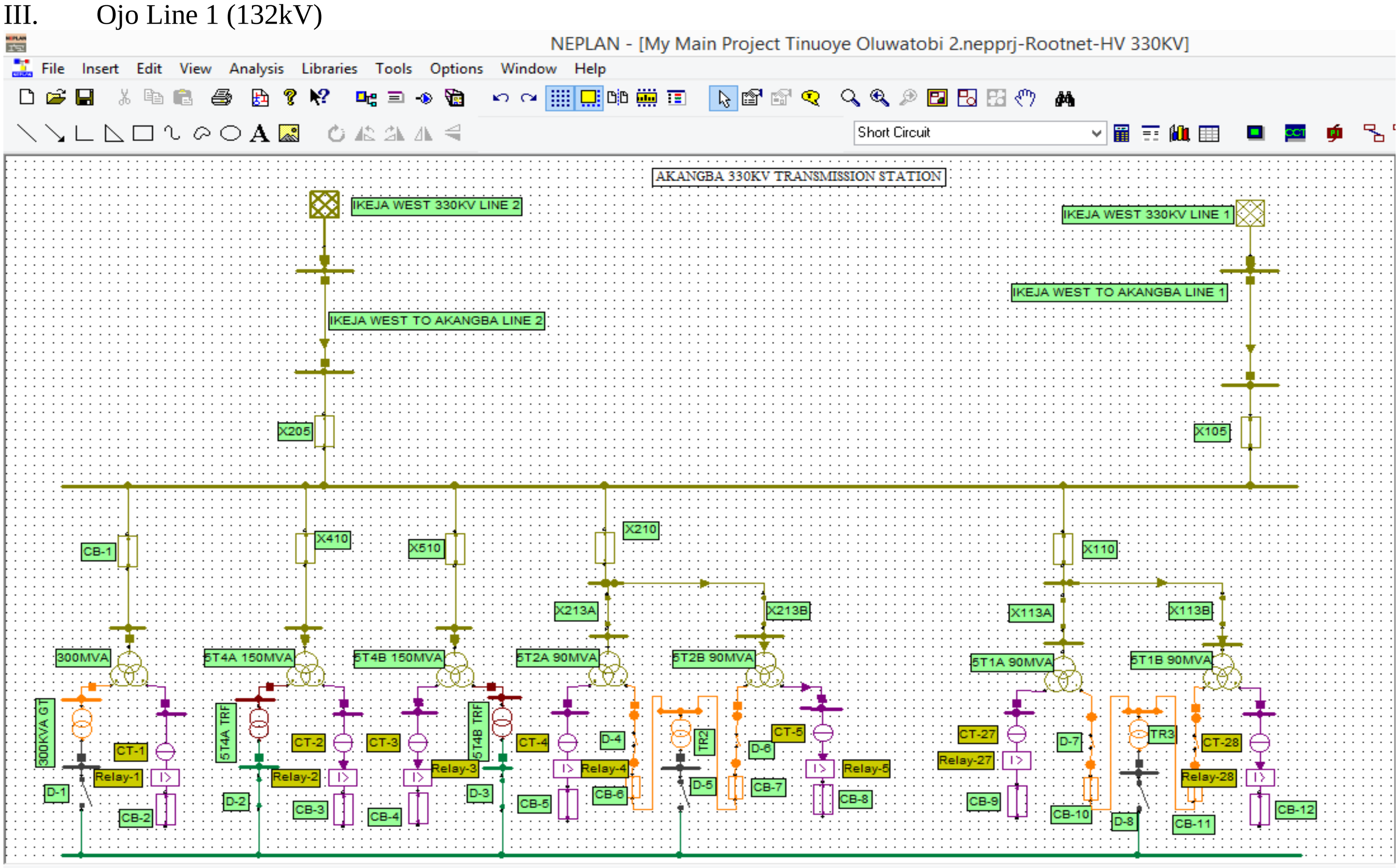


Figure 3: NEPLAN tool Implementation of Akangba 330kV Network

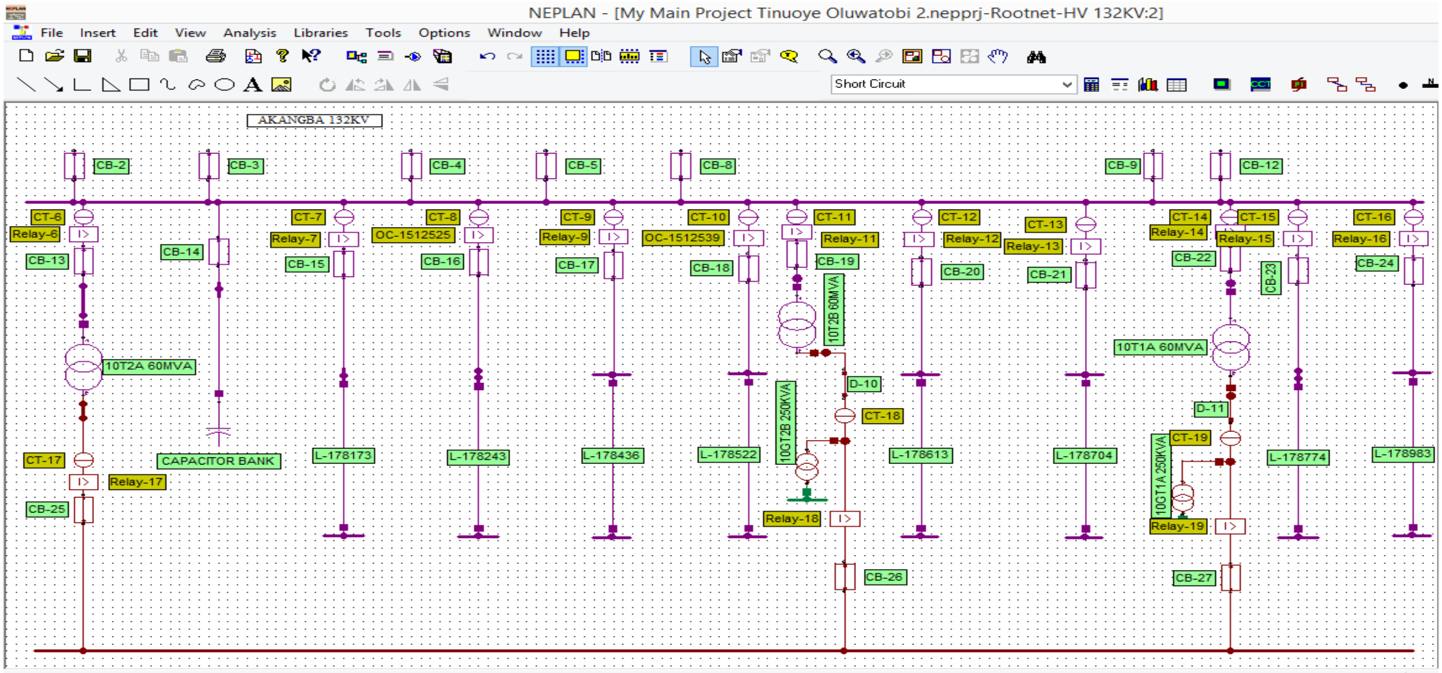


Figure 4: NEPLAN tool Implementation of Akangba 132kV Network

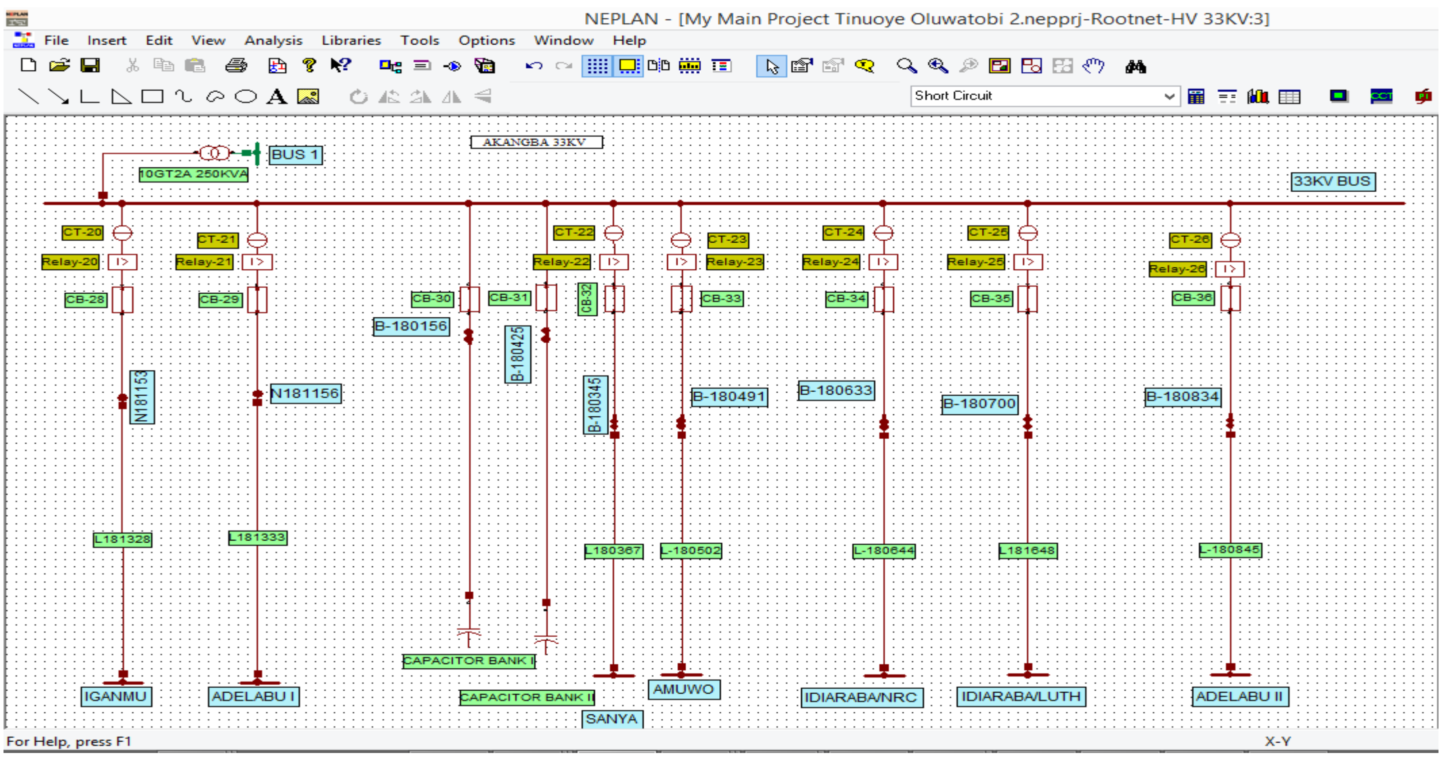


Figure 5: NEPLAN tool Implementation of Akangba 33kV Network

3.0 RESULTS AND DISCUSSION

The NEPLAN software was used to verify the effect of the newly acquired 300MVA transformer on the protection scheme. This was implemented by opening and closing the breaker (CB-1) between the 300MVA transformer and the 330kV line from Ikeja west in figure 3.

The CB-1 open scenario 1 is the present existing situation while the CB-1 closed scenario 2 is the expansion that was just implemented. The system is assumed to be under load condition and the required data gathered for the system representation in NEPLAN include;

- Single line network diagram of Akangba power station,

- Parameters of transformers in each substation involved,
- Types and rating of circuit breakers,
  - Distance of transmission lines and type/rating of conductors (see Appendix A),
  - Power readings on incoming feeders to the substation involved,
  - Peak demand and present load profile (see Appendix B).

The two scenarios are depicted in Figure 6 and 7 below to show the effect of the expansion work (i.e., the introduction of the new 300MVA) to the existing Akangba Transmission substation network. Scenario 1 (Figure 6) is the existing condition of the network while scenario 2 (Figure 7) is the condition after the 300MVA transformer has been added to the network.

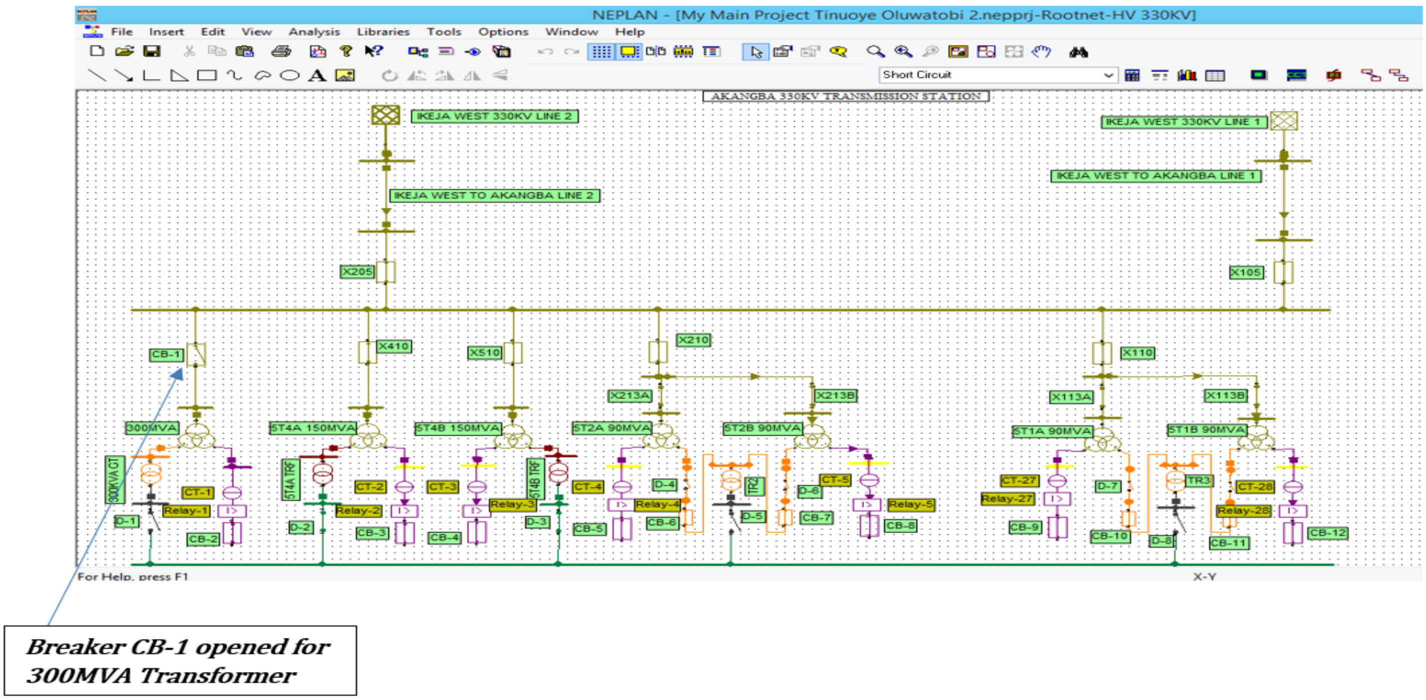


Figure 6: Scenario 1 (CB-1 Opened for the 300MVA Transformer)

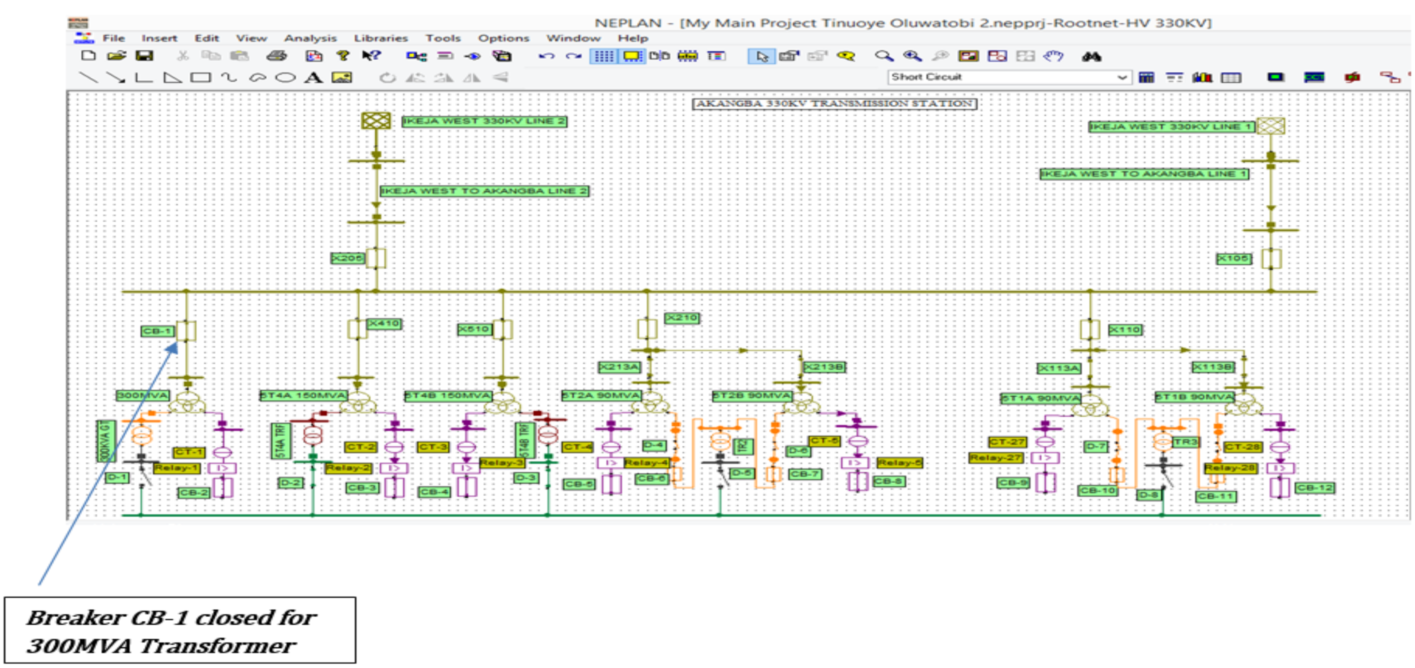
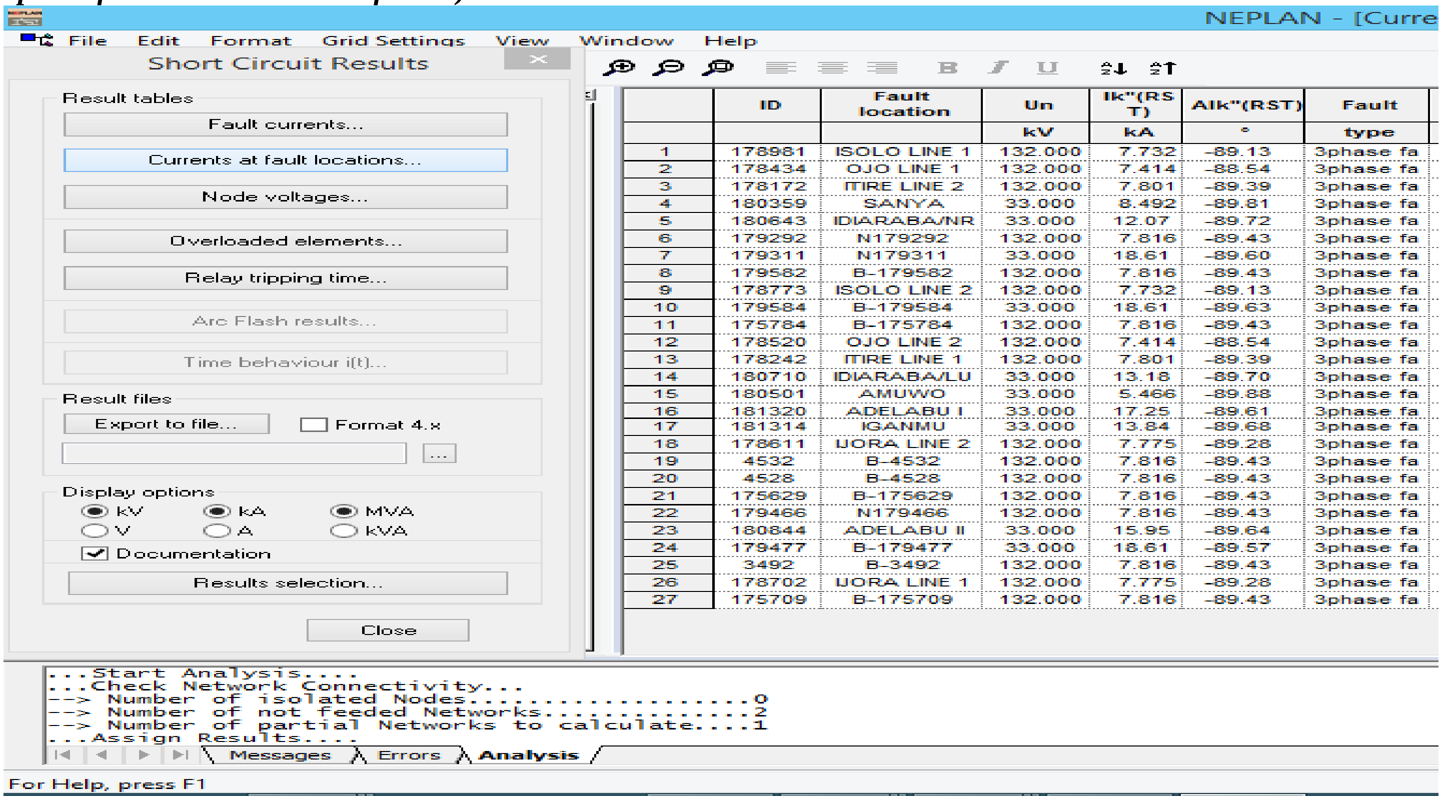


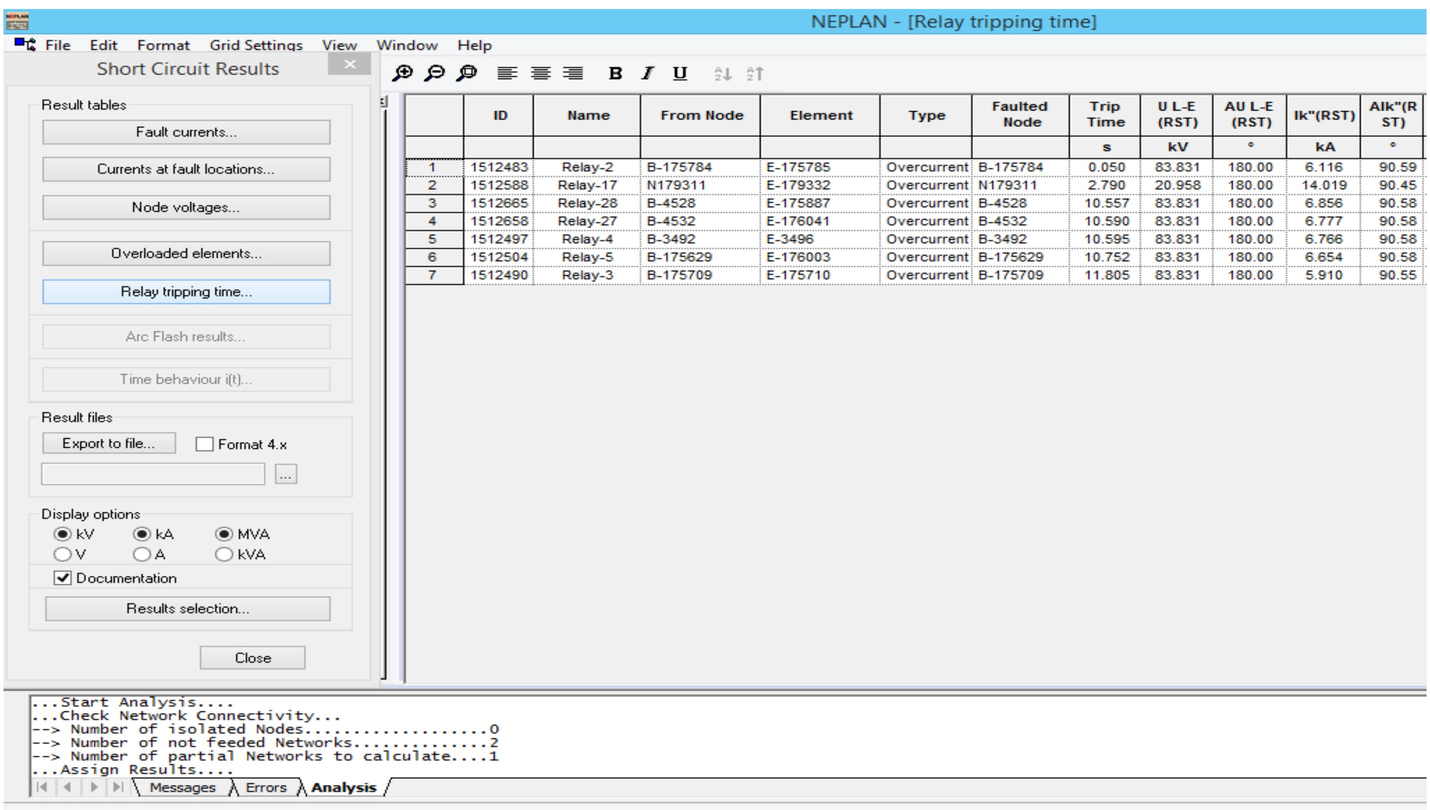
Figure 7: Scenario 2 (CB-1 Closed for the 300MVA Transformer)

3.1 Simulated Results for Three Phase and Single Line to Ground Fault for Scenario 1 and 2.Scenario 1 (CB-1 opened for the 300MVA Transformer)



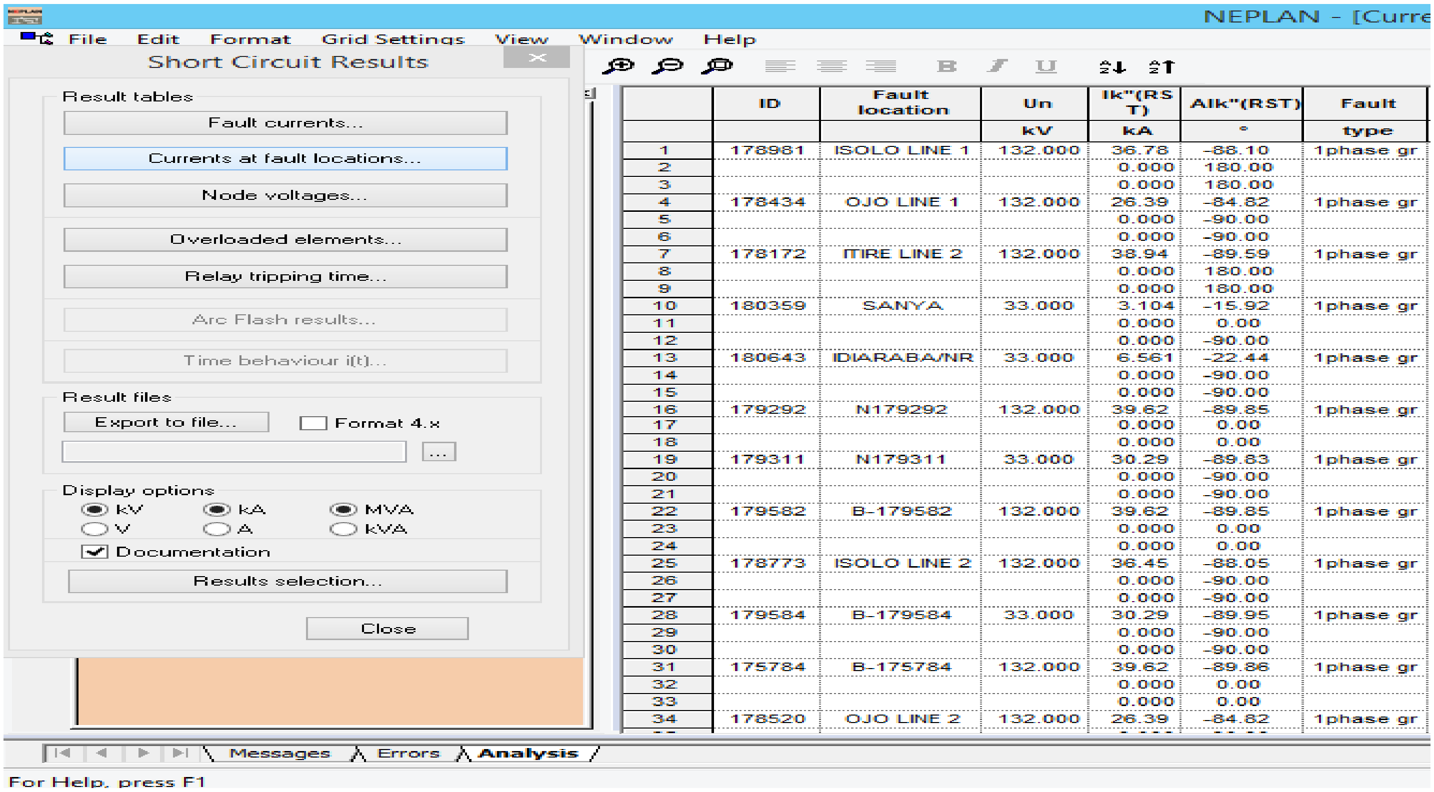
	ID	Fault location	Un	Ik"(RST)	AIk"(RST)	Fault
			kV	kA	°	type
1	178981	ISOLO LINE 1	132.000	7.732	-89.13	3phase fa
2	178434	OJO LINE 1	132.000	7.414	-88.54	3phase fa
3	178172	ITIRE LINE 2	132.000	7.801	-89.39	3phase fa
4	180359	SANYA	33.000	8.492	-89.81	3phase fa
5	180643	IDIARABA/NR	33.000	12.07	-89.72	3phase fa
6	179292	N179292	132.000	7.816	-89.43	3phase fa
7	179311	N179311	33.000	18.61	-89.60	3phase fa
8	179582	B-179582	132.000	7.816	-89.43	3phase fa
9	178773	ISOLO LINE 2	132.000	7.732	-89.13	3phase fa
10	179584	B-179584	33.000	18.61	-89.63	3phase fa
11	175784	B-175784	132.000	7.816	-89.43	3phase fa
12	178520	OJO LINE 2	132.000	7.414	-88.54	3phase fa
13	178242	ITIRE LINE 1	132.000	7.801	-89.39	3phase fa
14	180710	IDIARABA/LU	33.000	13.18	-89.70	3phase fa
15	180501	AMUWO	33.000	5.466	-89.88	3phase fa
16	181320	ADELABU I	33.000	17.25	-89.61	3phase fa
17	181314	IGANMU	33.000	13.84	-89.68	3phase fa
18	178611	IJORA LINE 2	132.000	7.775	-89.28	3phase fa
19	4532	B-4532	132.000	7.816	-89.43	3phase fa
20	4528	B-4528	132.000	7.816	-89.43	3phase fa
21	175629	B-175629	132.000	7.816	-89.43	3phase fa
22	179466	N179466	132.000	7.816	-89.43	3phase fa
23	180844	ADELABU II	33.000	15.95	-89.64	3phase fa
24	179477	B-179477	33.000	18.61	-89.57	3phase fa
25	3492	B-3492	132.000	7.816	-89.43	3phase fa
26	178702	IJORA LINE 1	132.000	7.775	-89.28	3phase fa
27	175709	B-175709	132.000	7.816	-89.43	3phase fa

Figure 8: Result of Three Phase Fault with 300MVA Transformer Breaker Opened



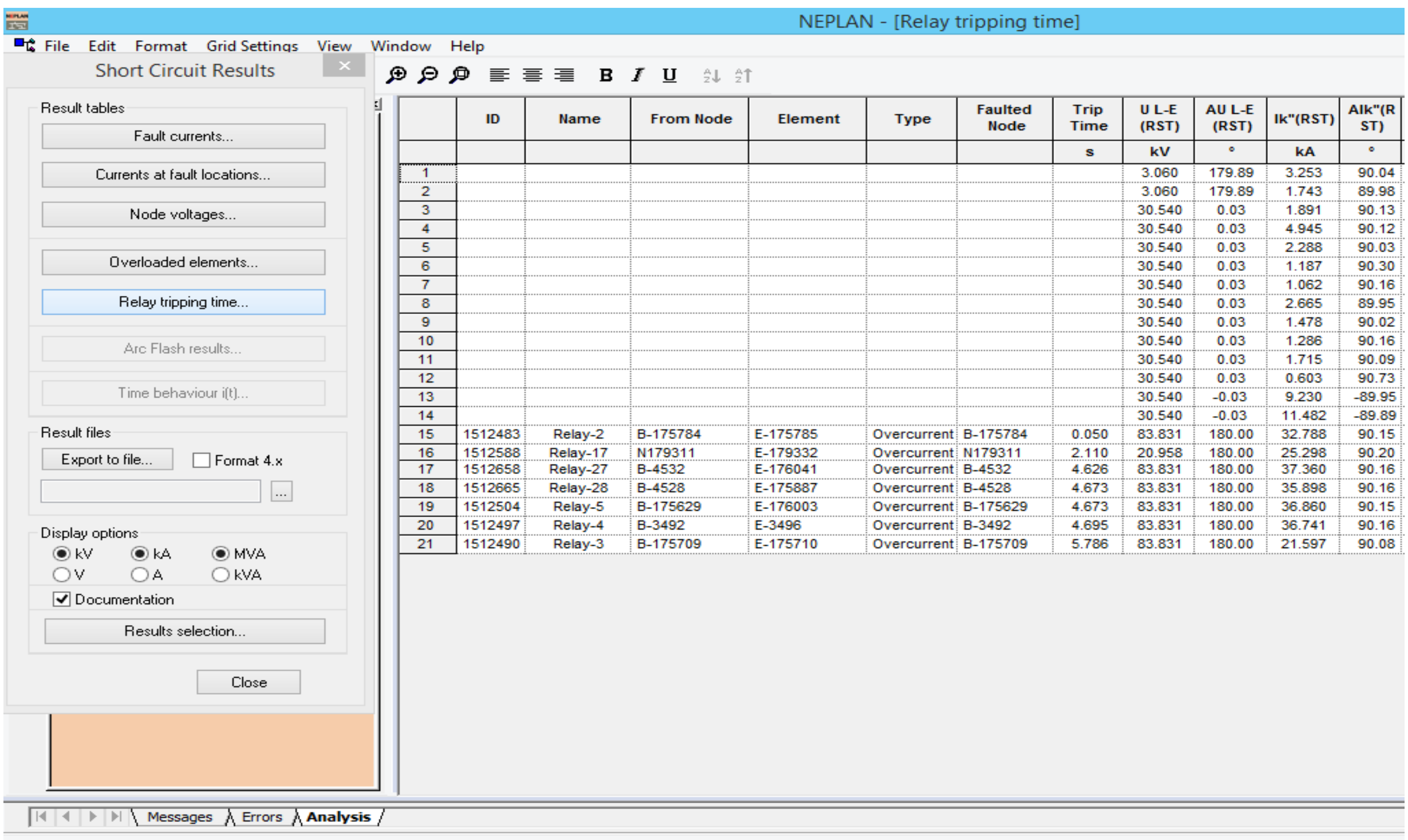
	ID	Name	From Node	Element	Type	Faulted Node	Trip Time	U L-E (RST)	AU L-E (RST)	Ik"(RST)	AIk"(RST)
							s	kV	°	kA	°
1	1512483	Relay-2	B-175784	E-175785	Overcurrent	B-175784	0.050	83.831	180.00	6.116	90.59
2	1512588	Relay-17	N179311	E-179332	Overcurrent	N179311	2.790	20.958	180.00	14.019	90.45
3	1512665	Relay-28	B-4528	E-175887	Overcurrent	B-4528	10.557	83.831	180.00	6.856	90.58
4	1512658	Relay-27	B-4532	E-176041	Overcurrent	B-4532	10.590	83.831	180.00	6.777	90.58
5	1512497	Relay-4	B-3492	E-3496	Overcurrent	B-3492	10.595	83.831	180.00	6.766	90.58
6	1512504	Relay-5	B-175629	E-176003	Overcurrent	B-175629	10.752	83.831	180.00	6.654	90.58
7	1512490	Relay-3	B-175709	E-175710	Overcurrent	B-175709	11.805	83.831	180.00	5.910	90.55

Figure 9: Result of Three Phase Fault Relay Trip Time with 300MVA Transformer Breaker Opened



	ID	Fault location	Un	Ik"(RST)	Alk"(RST)	Fault
			kV	kA	°	type
1	178981	ISOLO LINE 1	132.000	36.78	-88.10	1phase gr
2				0.000	180.00	
3				0.000	180.00	
4	178434	OJO LINE 1	132.000	26.39	-84.82	1phase gr
5				0.000	-90.00	
6				0.000	-90.00	
7	178172	ITIRE LINE 2	132.000	38.94	-89.59	1phase gr
8				0.000	180.00	
9				0.000	180.00	
10	180359	SANYA	33.000	3.104	-15.92	1phase gr
11				0.000	0.00	
12				0.000	-90.00	
13	180643	IDIARABA/NR	33.000	6.561	-22.44	1phase gr
14				0.000	-90.00	
15				0.000	-90.00	
16	179292	N179292	132.000	39.62	-89.85	1phase gr
17				0.000	0.00	
18				0.000	0.00	
19	179311	N179311	33.000	30.29	-89.83	1phase gr
20				0.000	-90.00	
21				0.000	-90.00	
22	179582	B-179582	132.000	39.62	-89.85	1phase gr
23				0.000	0.00	
24				0.000	0.00	
25	178773	ISOLO LINE 2	132.000	36.45	-88.05	1phase gr
26				0.000	-90.00	
27				0.000	-90.00	
28	179584	B-179584	33.000	30.29	-89.95	1phase gr
29				0.000	-90.00	
30				0.000	-90.00	
31	175784	B-175784	132.000	39.62	-89.86	1phase gr
32				0.000	0.00	
33				0.000	0.00	
34	178520	OJO LINE 2	132.000	26.39	-84.82	1phase gr

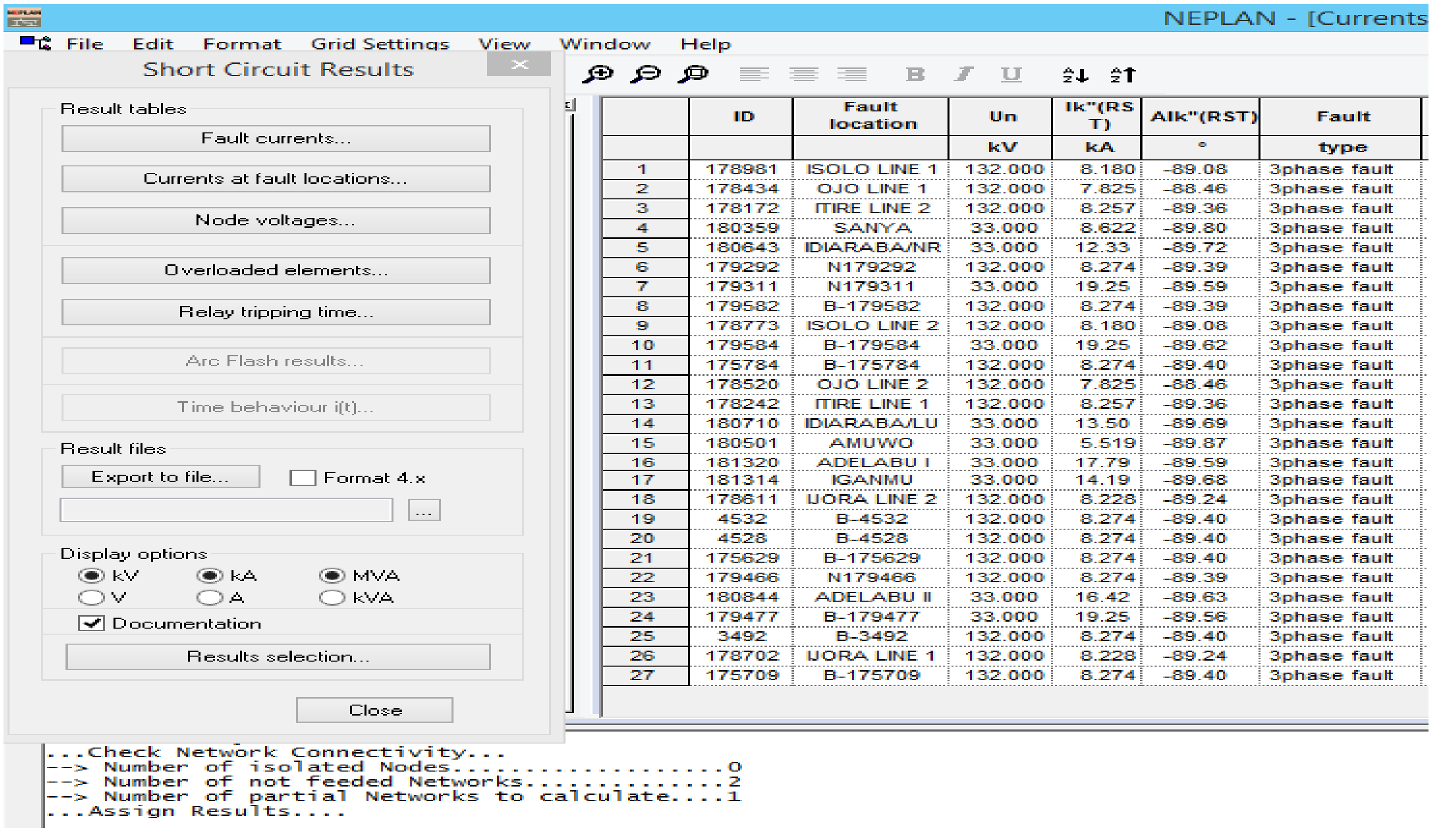
Figure 10: Result of Single Phase to Ground Fault with 300MVA Transformer Breaker Opened



	ID	Name	From Node	Element	Type	Faulted Node	Trip Time	U L-E (RST)	AU L-E (RST)	Ik"(RST)	Alk"(RST)
							s	kV	°	kA	°
1								3.060	179.89	3.253	90.04
2								3.060	179.89	1.743	89.98
3								30.540	0.03	1.891	90.13
4								30.540	0.03	4.945	90.12
5								30.540	0.03	2.288	90.03
6								30.540	0.03	1.187	90.30
7								30.540	0.03	1.062	90.16
8								30.540	0.03	2.665	89.95
9								30.540	0.03	1.478	90.02
10								30.540	0.03	1.286	90.16
11								30.540	0.03	1.715	90.09
12								30.540	0.03	0.603	90.73
13								30.540	-0.03	9.230	-89.95
14								30.540	-0.03	11.482	-89.89
15	1512483	Relay-2	B-175784	E-175785	Overcurrent	B-175784	0.050	83.831	180.00	32.788	90.15
16	1512588	Relay-17	N179311	E-179332	Overcurrent	N179311	2.110	20.958	180.00	25.298	90.20
17	1512658	Relay-27	B-4532	E-176041	Overcurrent	B-4532	4.626	83.831	180.00	37.360	90.16
18	1512665	Relay-28	B-4528	E-175887	Overcurrent	B-4528	4.673	83.831	180.00	35.898	90.16
19	1512504	Relay-5	B-175629	E-176003	Overcurrent	B-175629	4.673	83.831	180.00	36.860	90.15
20	1512497	Relay-4	B-3492	E-3496	Overcurrent	B-3492	4.695	83.831	180.00	36.741	90.16
21	1512490	Relay-3	B-175709	E-175710	Overcurrent	B-175709	5.786	83.831	180.00	21.597	90.08

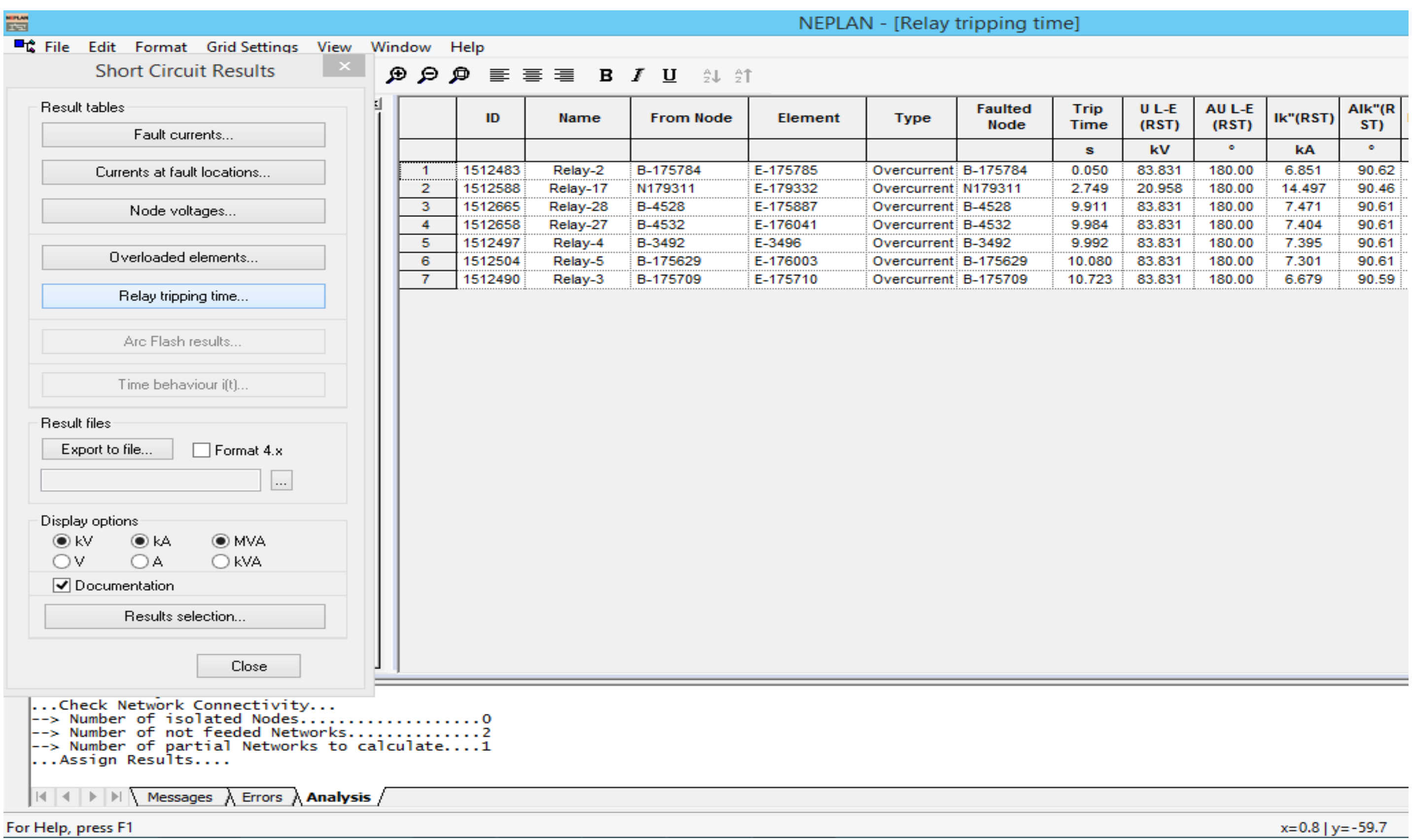
Figure 11: Result of Single Phase to Ground Fault Relay Trip Time with 300MVA Transformer Breaker Opened

Scenario 2 (CB-1 closed for the 300MVA Transformer)



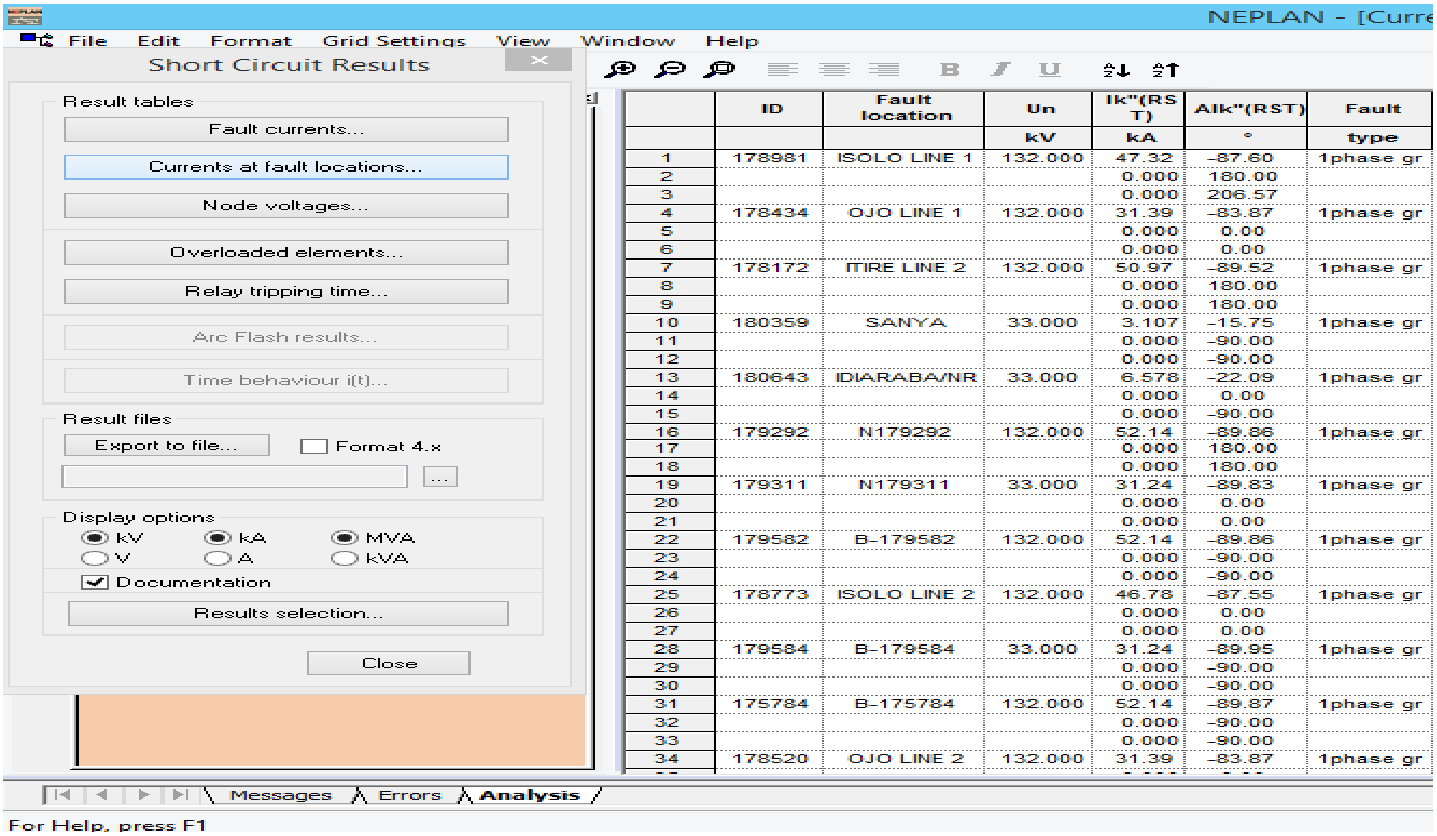
	ID	Fault location	Un	Ik"(RST)	AIk"(RST)	Fault type
			kV	kA	°	
1	178981	ISOLO LINE 1	132.000	8.180	-89.08	3phase fault
2	178434	OJO LINE 1	132.000	7.825	-88.46	3phase fault
3	178172	ITIRE LINE 2	132.000	8.257	-89.36	3phase fault
4	180359	SANYA	33.000	8.622	-89.80	3phase fault
5	180643	IDIARABA/NR	33.000	12.33	-89.72	3phase fault
6	179292	N179292	132.000	8.274	-89.39	3phase fault
7	179311	N179311	33.000	19.25	-89.59	3phase fault
8	179582	B-179582	132.000	8.274	-89.39	3phase fault
9	178773	ISOLO LINE 2	132.000	8.180	-89.08	3phase fault
10	179584	B-179584	33.000	19.25	-89.62	3phase fault
11	175784	B-175784	132.000	8.274	-89.40	3phase fault
12	178520	OJO LINE 2	132.000	7.825	-88.46	3phase fault
13	178242	ITIRE LINE 1	132.000	8.257	-89.36	3phase fault
14	180710	IDIARABA/LU	33.000	13.50	-89.69	3phase fault
15	180501	AMUWO	33.000	5.519	-89.87	3phase fault
16	181320	ADELABU I	33.000	17.79	-89.59	3phase fault
17	181314	IGANMU	33.000	14.19	-89.68	3phase fault
18	178611	IJORA LINE 2	132.000	8.228	-89.24	3phase fault
19	4532	B-4532	132.000	8.274	-89.40	3phase fault
20	4528	B-4528	132.000	8.274	-89.40	3phase fault
21	175629	B-175629	132.000	8.274	-89.40	3phase fault
22	179466	N179466	132.000	8.274	-89.39	3phase fault
23	180844	ADELABU II	33.000	16.42	-89.63	3phase fault
24	179477	B-179477	33.000	19.25	-89.56	3phase fault
25	3492	B-3492	132.000	8.274	-89.40	3phase fault
26	178702	IJORA LINE 1	132.000	8.228	-89.24	3phase fault
27	175709	B-175709	132.000	8.274	-89.40	3phase fault

Figure 12: Result of Three Phase Fault with 300MVA Transformer Breaker Closed



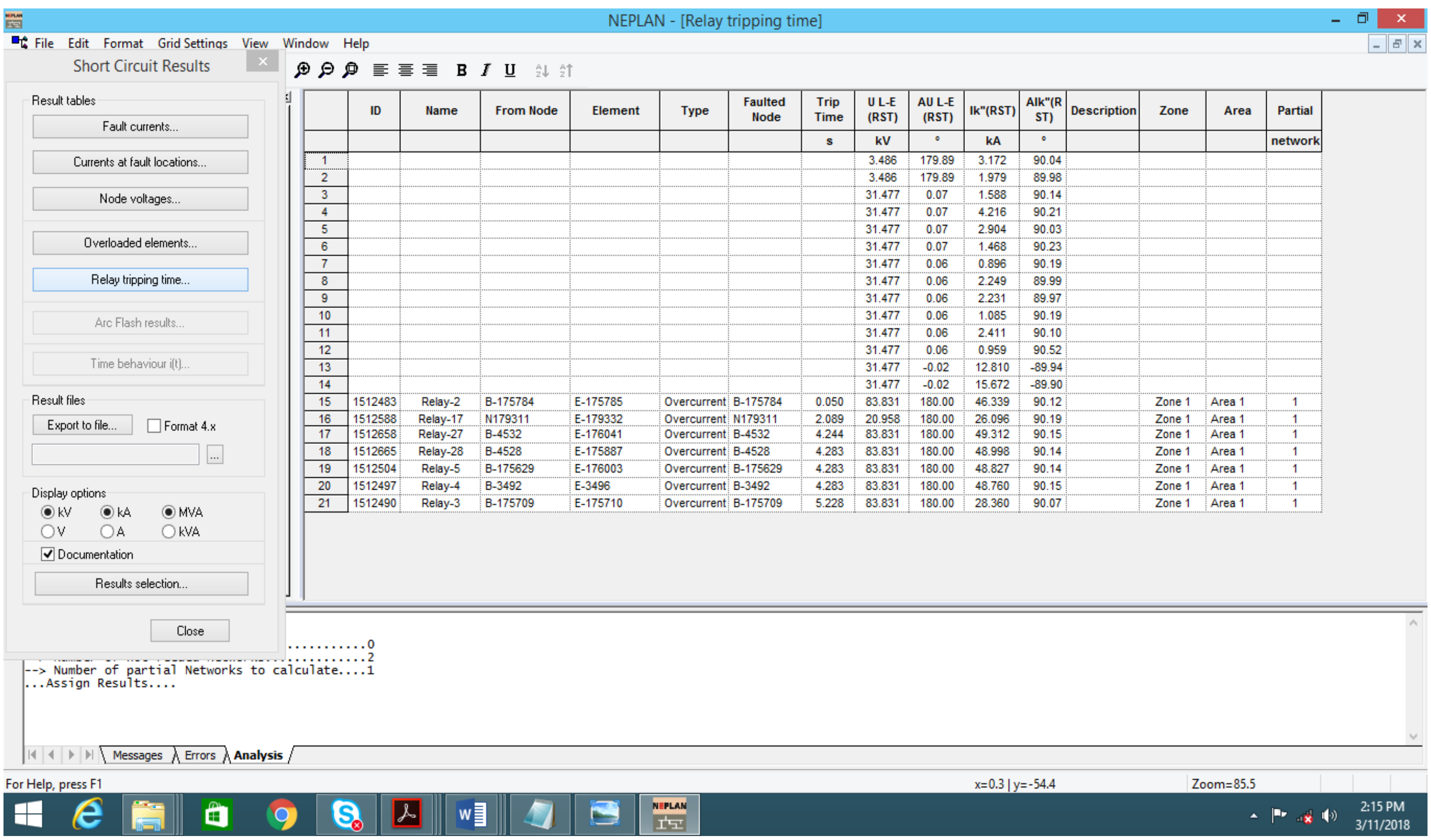
	ID	Name	From Node	Element	Type	Faulted Node	Trip Time	U L-E (RST)	AU L-E (RST)	Ik"(RST)	AIk"(RST)
							s	kV	°	kA	°
1	1512483	Relay-2	B-175784	E-175785	Overcurrent	B-175784	0.050	83.831	180.00	6.851	90.62
2	1512588	Relay-17	N179311	E-179332	Overcurrent	N179311	2.749	20.958	180.00	14.497	90.46
3	1512665	Relay-28	B-4528	E-175887	Overcurrent	B-4528	9.911	83.831	180.00	7.471	90.61
4	1512658	Relay-27	B-4532	E-176041	Overcurrent	B-4532	9.984	83.831	180.00	7.404	90.61
5	1512497	Relay-4	B-3492	E-3496	Overcurrent	B-3492	9.992	83.831	180.00	7.395	90.61
6	1512504	Relay-5	B-175629	E-176003	Overcurrent	B-175629	10.080	83.831	180.00	7.301	90.61
7	1512490	Relay-3	B-175709	E-175710	Overcurrent	B-175709	10.723	83.831	180.00	6.679	90.59

Figure 13: Result of Three Phase Fault Trip Time 300MVA Transformer Breaker Closed



	ID	Fault location	Un	Ik"(RST)	AIk"(RST)	Fault
			kV	kA	°	type
1	178981	ISOLO LINE 1	132.000	47.32	-87.60	1phase gr
2				0.000	180.00	
3				0.000	206.57	
4	178434	OJO LINE 1	132.000	31.39	-83.87	1phase gr
5				0.000	0.00	
6				0.000	0.00	
7	178172	ITIRE LINE 2	132.000	50.97	-89.52	1phase gr
8				0.000	180.00	
9				0.000	180.00	
10	180359	SANYA	33.000	3.107	-15.75	1phase gr
11				0.000	-90.00	
12				0.000	-90.00	
13	180643	IDIARABA/NR	33.000	6.578	-22.09	1phase gr
14				0.000	0.00	
15				0.000	-90.00	
16	179292	N179292	132.000	52.14	-89.86	1phase gr
17				0.000	180.00	
18				0.000	180.00	
19	179311	N179311	33.000	31.24	-89.83	1phase gr
20				0.000	0.00	
21				0.000	0.00	
22	179582	B-179582	132.000	52.14	-89.86	1phase gr
23				0.000	-90.00	
24				0.000	-90.00	
25	178773	ISOLO LINE 2	132.000	46.78	-87.55	1phase gr
26				0.000	0.00	
27				0.000	0.00	
28	179584	B-179584	33.000	31.24	-89.95	1phase gr
29				0.000	-90.00	
30				0.000	-90.00	
31	175784	B-175784	132.000	52.14	-89.87	1phase gr
32				0.000	-90.00	
33				0.000	-90.00	
34	178520	OJO LINE 2	132.000	31.39	-83.87	1phase gr

Figure 14: Result of Single Phase to Ground Fault with 300MVA Transformer Breaker Closed



	ID	Name	From Node	Element	Type	Faulted Node	Trip Time	U L-E (RST)	AU L-E (RST)	Ik"(RST)	AIk"(RST)	Description	Zone	Area	Partial
							s	kV	°	kA	°				network
1								3.486	179.89	3.172	90.04				
2								3.486	179.89	1.979	89.98				
3								31.477	0.07	1.588	90.14				
4								31.477	0.07	4.216	90.21				
5								31.477	0.07	2.904	90.03				
6								31.477	0.07	1.468	90.23				
7								31.477	0.06	0.896	90.19				
8								31.477	0.06	2.249	89.99				
9								31.477	0.06	2.231	89.97				
10								31.477	0.06	1.085	90.19				
11								31.477	0.06	2.411	90.10				
12								31.477	0.06	0.959	90.52				
13								31.477	-0.02	12.810	-89.94				
14								31.477	-0.02	15.672	-89.90				
15	1512483	Relay-2	B-175784	E-175785	Overcurrent	B-175784	0.050	83.831	180.00	46.339	90.12		Zone 1	Area 1	1
16	1512588	Relay-17	N179311	E-179332	Overcurrent	N179311	2.089	20.958	180.00	26.096	90.19		Zone 1	Area 1	1
17	1512658	Relay-27	B-4532	E-176041	Overcurrent	B-4532	4.244	83.831	180.00	49.312	90.15		Zone 1	Area 1	1
18	1512665	Relay-28	B-4528	E-175887	Overcurrent	B-4528	4.283	83.831	180.00	48.998	90.14		Zone 1	Area 1	1
19	1512504	Relay-5	B-175629	E-176003	Overcurrent	B-175629	4.283	83.831	180.00	48.827	90.14		Zone 1	Area 1	1
20	1512497	Relay-4	B-3492	E-3496	Overcurrent	B-3492	4.283	83.831	180.00	48.760	90.15		Zone 1	Area 1	1
21	1512490	Relay-3	B-175709	E-175710	Overcurrent	B-175709	5.228	83.831	180.00	28.360	90.07		Zone 1	Area 1	1

Figure 15: Result of Single Phase to Ground Fault Relay Trip Time with 300MVA Transformer Breaker Closed

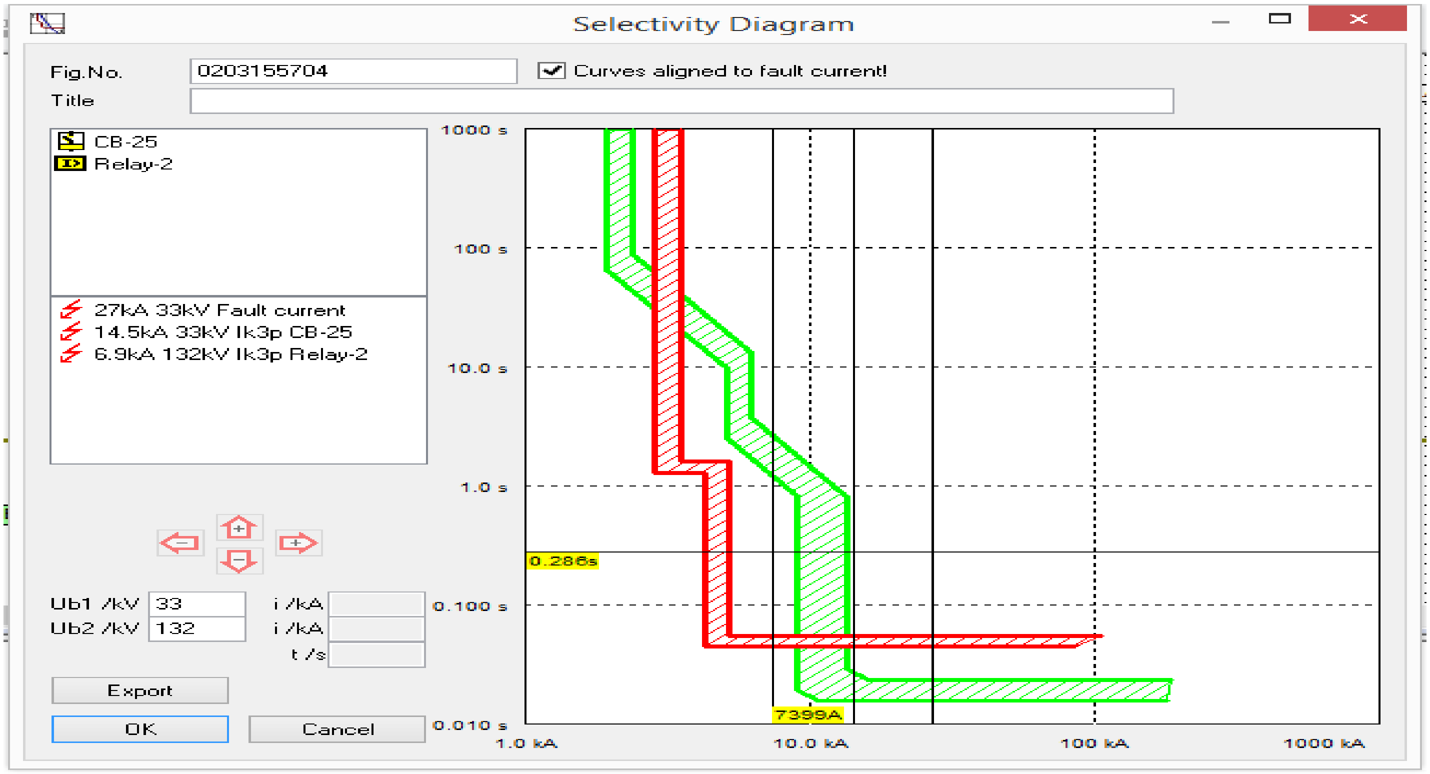


Figure 16: Time Current Curve

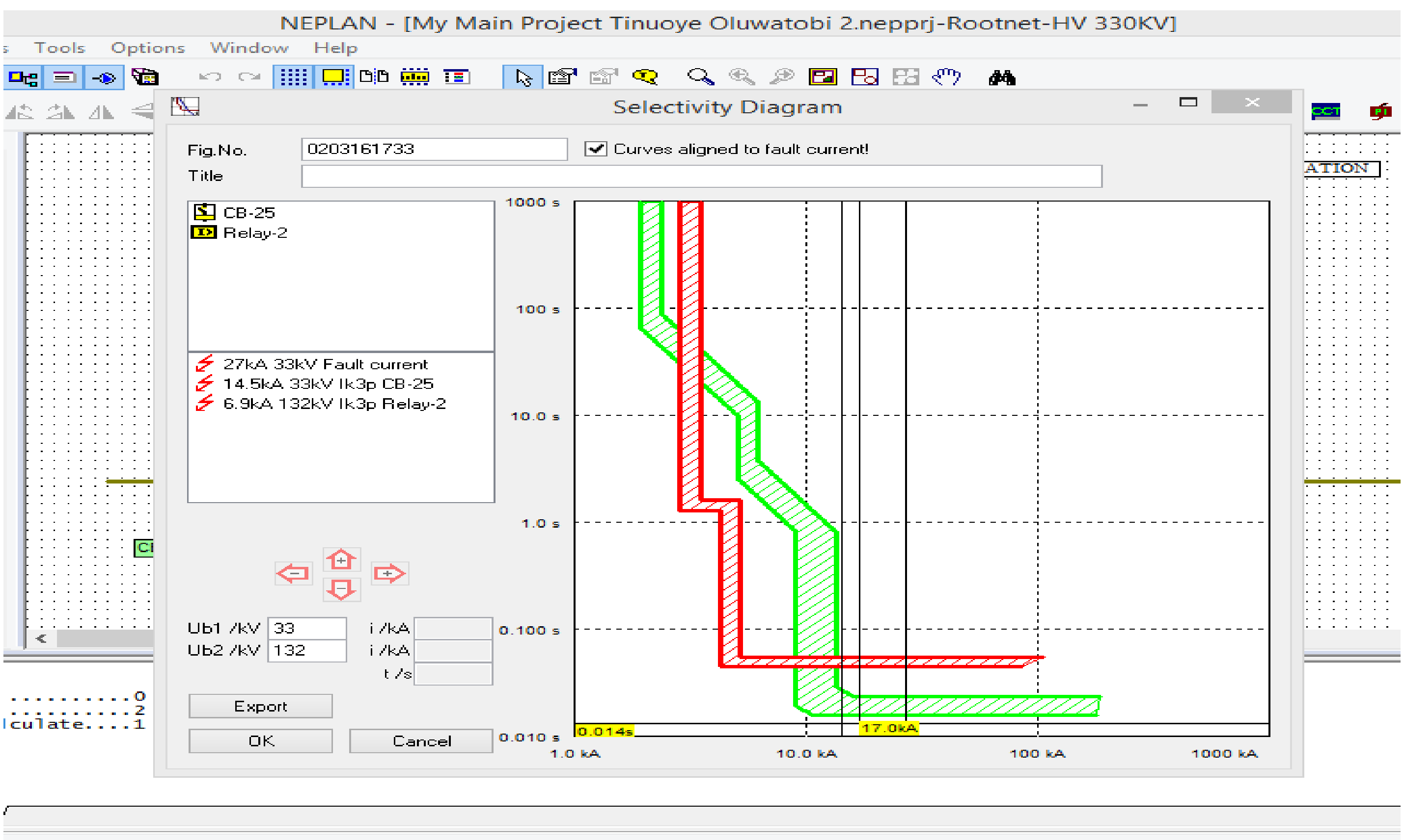


Figure 17: Time Current Curve

3.1 Discussion

Figure 6 above shows scenario 1 where breaker CB-1 interconnecting the 300MVA transformer to the 330KV bus is opened. Figure 7 shows scenario 2 where breaker CB-1 interconnecting the 300MVA transformer to the 330KV bus is closed. Scenario 2 also depicts the expansion of the network under construction. Three phase and single line to ground short circuit faults were simulated for the two scenarios to determine the fault current on each of the 132kV and 33kV feeders.

Condition 1: (300MVA Transformer breaker Opened and three-phase fault simulated), Figure 8 shows the fault locations, the fault current and phase angle when a three-phase fault was simulated. Figure 9 indicates the tripping time and fault current at which the protective devices (relay) on the power network responds under the condition of a three-phase fault.

Condition 2: (300MVA Transformer breaker opened and Single phase to ground fault simulated), Figure 10 displays the fault locations, fault current and phase angle for a single phase to ground fault and Figure 11 is the tripping time and fault current at which the relay in the zone of protection operates.

Condition 3: (300MVA Transformer breaker closed and three-phase fault simulated), Figure 12 also reveals the fault locations, associated fault current and phase angle under condition 3. The tripping time and fault current for the protective device is as indicated in Figure 13.

Condition 4: (300MVA Transformer breaker closed and Single phase to ground fault simulated), Figure 14 indicates the fault current, the location and phase angles of condition 4 with figure 15 also showing the tripping time and fault current for the protective instruments.

The comparison of results of Figure 8 versus figure 12, as well as figure 10 versus figure 14 when the CB-1 is opened and closed for different fault types shows variation ranges of 10-20%. The variation is much more significant on the single phase to ground fault than the three-phase fault. This goes to prove that expansion of power network, changes in switching configuration or replacement of power components with lesser or higher specification on a power network has significant effect on the fault current that can flow in the system. This can also impact the protection scheme, cause outage of healthy part of the power network or damage the critical power components if these changes are not managed with a simulation software.

Furthermore, as the fault current in the locations increased from the scenario earlier highlighted, the tripping time of relay has an inverse relationship. As current increases, the tripping time reduces which is depicted in figure 9, Figure 13 for three phase fault and Figure 11, figure 15 for single line to ground fault.

Figures 16 and 17 are the time-current curve (TCC) plots which is used to achieve coordination of protective devices. It presents a graphical view of the protection system for protection Engineers to make decisions and adjustments on the sequence of operation of protective devices in a particular power network. For the simulations in this article, the TCC is shown in figures 16 and 17 with the fault current plots on the abscissa and the corresponding tripping time on the ordinate.

Protection engineers must therefore take note of changes when planning protection coordination and relay setting. This will ensure expensive power system are not damaged because of improper relay setting, human safety is not put at risk because of poor design. This will also ensure provision of reliable power supply to the yearning populace.

4.0 CONCLUSION

As the demand for power supply increases, there will always be the need to constantly expand the power network. This will in turn necessitate the review of existing protection system to be able to guarantee adequate protection and quick isolation of fault part of the network. Any Additional component on the power network or replacement of power system component with a different specification of equipment has effect on the amount of fault current flowing in the system when there is a fault.

Protection engineers must be well versed in the analysis of faulted power systems so that they can make appropriate relay settings and analyze complex system operations. Analysis of the Akangba Transmission substation shows variation ranges of 10-20% of fault current on the feeders when a new 300MVA was added to the network. This variation is significant and must be taken into consideration when reviewing the present relay setting in the station. It is my hope that this article will stimulate future study of the Nigeria transmission network as an entity, with a centrally managed protection scheme software and database. This will ensure appropriate study of the network protection and aid proper decision making on the relay settings. It also has the advantage of creating a balance in power distribution, and reduction of damage to expensive power system components (i.e., transformers).

The following recommendations are suggested for improvement of distribution of Akangba TS:

- Embrace a power analysis software to analyze periodically the power system to ensure proper setting of relay and coordination especially when changes are made on the network

- Replace vandalized pilot cables, old transformers (most of which were manufactured in 1968) and re-terminate them for the remote control switching to be enabled instead of the manual switching done at the switchgear. (see Appendix C, Appendix D and Appendix E)
- Restore decommissioned reactors to limit fault current in the power network
- Purchase additional 330kV breakers and relays to separate the two 90MVA sharing the same breaker (See Appendix F and Appendix G).

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CONFLICT OF INTEREST

There is no conflict of interest associated with this work

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[21]

Appendix A: Impedance and distance of Akangba outgoing transmission lines

S/N	LINE	LINE IMPEDANCE(Z1)		LINE IMPEDANCE(Z0)		LENGTH(KM)
		R(ohm)	X(ohm)	R(ohm)	X(ohm)	
1	Akangba - Itire 132kv	0.0021127	0.006772	0.005664	0.02326	3
2	Akangba -Ijora 132kv	0.0056477	0.00112954	0.012672	0.03636	5
3	Akangba -Isolo 132kv	0.0082362	0.0164724	0.013573	0.03656	7
4	Akangba - Ojo 132kv	0.0112678	0.0361177	0.030212	0.12409	16
5	Akangba- Apapa Rd 132kv	0.0094128	0.0188256	0.021121	0.0606	8
6	Akangba-Iganmu 33kv	0.00142	0.125	0.00773	0.0745	3.1
7	Akangba - Adelabu 1	0.0134	0.1272	0.01772	0.0824	0.7
8	Akangba – Sanya	0.01452	0.122	0.0177	0.0724	11
9	Akangba – Amuwo	0.0164	0.122	0.01712	0.0724	22.2
10	Akangba - Idiaraba/NRC	0.01453	0.122	0.01731	0.0724	5
11	Akangba - Idiaraba/Luth	0.01324	0.122	0.0174	0.0724	3.8
12	Akangba – Ijora causeway	0.01632	0.124	0.0178	0.0824	6.4
13	Akangba - Yaba/NRC	0.01624	0.1223	1.773	0.07224	6.6
14	Akangba - Orile NRC	0.01522	0.1222	0.01877	0.0732	12.6

Appendix B: Akangba T.S Load profile

TIME (HRS)	AKANGBA 132KV T.S.	IJORA 132KV T.S.	ISOLO 132KV T.S.	ITIRE 132KV T.S.	OJO 132KV T.S.	ILUPEJU 132KV T.S.	TOTAL (MW)
1:00	28	15	14.8	11.1	25.6	11.7	106.2
2:00	21	15	5.2	28.5	30.7	13.9	114.3
3:00	22	15	6.2	0	30.6	15.4	89.2
4:00	19	18	6.2	0	27.5	17.7	88.4
5:00	33	18.6	9.8	0	33.9	0	95.3
6:00	14	24.5	9.7	13.5	36.6	0	98.3
7:00	13	30	15.6	10.4	37.5	9.5	116
8:00	14	0	9.1	2.7	32.6	13.5	71.9
9:00	19	4.4	8.6	23.9	0	16.2	72.1
10:00	19	10	16.4	16.6	15.3	8.4	85.7
11:00	25	10	21.1	19.1	0	15.2	90.4
12:00	26	16	27.9	21.9	5.4	15.2	112.4
13:00	24	15	18.4	9.9	10.2	0	77.5
14:00	16	0	19.6	0	0	10.7	46.3
15:00	23	7	19.8	14.4	0	11.9	76.1
16:00	22	8	14.4	17.2	11.2	20.2	93
17:00	23	8	12.3	10.7	16.1	0	70.1
18:00	36	18	19.2	22.5	15.4	10.2	121.3
19:00	30	22.5	20.2	18.5	17.2	10.7	119.1
20:00	27	22.5	16.6	17.2	4.6	10.9	98.8

TIME (HRS)	AKANGBA 132KV T.S.	IJORA 132KV T.S.	ISOLO 132KV T.S.	ITIRE 132KV T.S.	OJO 132KV T.S.	ILUPEJU 132KV T.S.	TOTAL (MW)
21:00	27	23	23.2	18.6	20	11.4	123.2
22:00	19	33.5	17.2	4.6	16	17	107.3
23:00	15	23.5	4.6	12.4	22.7	18.1	96.3
24:00:00	25	23.5	4.6	0	20.7	13.6	87.4
MORNING PEAK	33@0500 HRS	30@0700HRS	27.9@1200 HRS	28.5@0200 HRS	37.5@0700 HRS	17.7@0400 HRS	116@0700HRS
EVENING PEAK	36@1800 HRS	33.5@2200 HRS	23.2@2100 HRS	22.5@1800 HRS	22.7@2300 HRS	202@1600 HRS	123.2@2100 HRS

Appendix C: Akangba T.S Transformer Asset Inventory

S/N	ASSET DESCRIPTION	RATED VOLTAGE	DATE OF ACQUISITION/INSTALLATION	ASSET SERIAL NO	MODEL/CCT TYPE	NAME OF MANUFCTURER	MANUFACTURE DATE	ASSET CODE
1	90MVA TRANSFORMER	330/132KV	1968	14434	-	ASGEN	1968	5T1A
2	90MVA TRANSFORMER	330/132KV	1974	7430250101	SUB-MRD	MITSUBISHI	1974	5T1B
3	90MVA TRANSFORMER	330/132KV	1974	7430250201	SUB-MRD	MITSUBISHI	1974	5T2A
4	90MVA TRANSFORMER	330/132KV	1968	14436	-	ASGEN	1968	5T2B
5	150MVA TRANSFORMER	330/132KV	1985	8134480101	SUB-MRM	MITSUBISHI	1981	5T4A
6	150MVA TRANSFORMER	330/132KV	2009	90639171	SFSZ-1500/330	TBEA	2008	5T4B
7	60MVA TRANSFORMER	132/33KV	2010	541268	-	ABB POWER TECH		10T1A
8	60MVA TRANSFORMER	132/33KV	2011	320031	-	TRANSFORMER & RECTIFIER INDIA LTD	2009	10T2B
9	60MVA TRANSFORMER	132/33KV	2012	54LYPT10673-11		LEEEC	2010	10T2A

Appendix D: Akangba T.S Grounding Transformer asset inventory

S/N	Asset Description	Rated Voltage	Date of Acquisition/Installation	Asset Serial no	Name of Manufacturer	Manufacture Date	Asset Code
1	500KVA TRANSFORMER	13.800/.400 KV	1968	40560	MILANO	1968	5T1A&5T1B, 2x90MVA TRF
2	500KVA TRANSFORMER	13.800/.400 KV	1968	40558	MILANO	1968	5T2A, 90MVA TRF
3	500KVA TRANSFORMER	13.800/.400 KV	1968	40559	MILANO	1968	5T2B, 90MVA TRF
4	540KVA TRANSFORMER	33/.415KV	1985	271217	MELCO	N/A	5T4A,150MVA TRF
5	540KVA TRANSFORMER	33/.415KV					5T4B, 150MVATRF

Appendix E: Transformer parameters

S/N	ASSET DESCRIPTION	ASSET CODE	Ur1 (kv)	Ur2 (kv)	Ur3 (kv)	Sr12 (MVA)	Sr23 (MVA)	Sr31 (MVA)	Ukr (1) 12 (%)	Ukr (1) 23 (%)	Ukr (1) 31 (%)	Ukr (0) 12 (%)	Ukr (0) 23 (%)	Ukr (0) 31 (%)
1	90MVA TRANSFORMER	5T1A	330	132	13.8	90	30	30	11.27	5.91	2.19	10.41	4.31	1.67
2	90MVA TRANSFORMER	5T1B	330	13.8	132	30	30	90	6.73	2.23	12.27	5.47	1.79	11.34
3	90MVA TRANSFORMER	5T2A	330	132	13.8	90	30	30	11.15	2.18	5.84	10.23	1.59	4.67
4	90MVA TRANSFORMER	5T2B	330	13.8	132	30	90	109	6.73	2.23	12.27	5.45	1.89	11.37
5	150MVA TRANSFORMER	5T4A	330	33	132	50	150	162	9.62	4.42	12.33	8.53	3.62	11.36
6	150MVA TRANSFORMER	5T4B	330	132	33	150	150	50	10.38	46.66	33.23	9.47	43.22	31.55
7	60MVA TRANSFORMER	10T1A	132	33	nil	60	nil	nil	4.85	nil	nil	4.85	nil	nil
8	60MVA TRANSFORMER	10T2B	132	33	nil	60	nil	nil	10.48	nil	nil	10.48	nil	nil
9	60MVA TRANSFORMER	10T2A	132	33	nil	60	nil	nil	10.33	nil	nil	10.33	nil	nil

Appendix F: Akangba T.S Relay asset inventory

S/N	ASSET DESCRIPTION	RATED VOLTAGE	ASSET IDENTITY/NUMENCLATURE	SERIAL NUMBER	MODEL/ CIRCUIT TYPE	NAME OF MANUFACTURER	MANFR DATE	ASSET CODE NOMENCLATURE
1	OVERCURRENT	33kv	ELECTRO MAGNETIC	B345155/38	ICM21Kop	BB	1968	AMUWO FEEDER
2	EARTH FAULT	33kv	ELECTRO MAGNETIC	B345155/320	ICM21Kp	BB	1970	
3	OVERCURRENT	33kv	ELECTRO MAGNETIC	B345155/1	ICM21Kop	BB	1968	
4	BUSBAR ZONE	33kv	ELECTRO MECHANICAL	B565683	CAGO,AK 420200	BB	N/A	
5	BUSBAR ZONE	33kv	ELECTRO MECHANICAL	B565682	CAGO,AK 420200	BB	N/A	
6	OVERCURRENT/ EARTHFAULT	33kv	STATIC	11020200		SCHNEIDER	N/A	ADELABU FEEDER 1
7	OVERCURRENT/ EARTHFAULT	33kv	STATIC	50088396	P122	MICOM	2001	ADELABU FEEDER 2
8	OVERCURRENT	33kv	ELECTRO MAGNETIC	B345155/1	ICM21Kop	BB	1968	IDIARABA/LUTH
9	EARTHFAULT	33kv	ELECTRO MANETIC	HE367781/390	ICM21Kp	BB	1972	
10	OVERCURRENT	33kv	ELECTRO MAGNETIC	B345155/38	ICM21Kop	BB	1968	
11	OVERCURRENT	33kv	ELECTRO MAGNETIC	B345155/38	ICM21Kop	BB	1968	IDIARABA/NRC
12	EARTHFAULT	33kv	ELECTRO MAGNETIC	B345155/44	ICM21Kp	BB	1971	
13	OVERCURRENT	33kv	ELECTRO MAGNETIC	B345155/1	ICM21Kop	BB	1968	
14	BUSBAR ZONE	33kv	ELECTRO MECHANICAL	B565675	CAGO,AK 420200	BB		
15	BUSBAR ZONE	33kv	ELECTRO MECHANICAL	B565674	CAGO,AK 420200	BB		
16	OVERCURRENT/ EARTHFAULT	33kv	STATIC	11030721	N/A	SCHNEIDER	N/A	IGANMU FEEDER
17	OVERCURRENT/ EARTHFAULT	33kv	STATIC	020203S	SEPAM 2000	MERLIN GERIN	N/A	SANYA FEEDER
18	OVERCURRENT	33kv	STATIC	BF110406 6851 LOR	7SJ8011-5EB90-IFAO/CC	SIEMENS	N/A	10T1A SEC
19	STANDBY EARTHFAULT	33kv	STATIC	BF110408 9105 LOR	7SJ8011-5EB90-IFAO/CC	SIEMENS	N/A	"
20	OVERCURRENT	33kv	STATIC	BF110407 7144	7SJ8011-5EB90-IFAO/CC	SIEMENS	N/A	10T2B SEC

21	OVERCURRENT/ EARTHFAULT	33kv	STATIC	11030719	MES120	SCHNEIDER	N/A	10T2A SEC

Appendix G: Akangba T.S 330kv and 132kv circuit breaker asset inventory

ASSET DESCRIPTION	RATED VOLTAGE(KV)	DATE OF ACQUISITION/INSTALLATION	ASSET IDENTITY NO(NUMENCLATURE)	ASSET SERIAL NO	MODEL/CCT TYPE	NAME OF MANUFACTURER	MANUFACTURE DATE	ASSET CODE(NOMENCLATURE)
IKEJA WEST LINE 1 BREAKER	330	1985	W3L	A02100	300-SFM-40A	MITSUBUSHI	1984	X105
BUS COUPLER BREAKER	330	1985	BUS COUPLER	HVFN 21168/2CEI C5621071	FE2	GEC	1983	X130
IKEJA WEST LINE 2 BREAKER	330	1984	W4L	HVFN 21168/2CEI C5621072	FE2	GEC	1983	X205
TRANSFORMER BREAKER	330	1985	5T1A&5T1B TRFS PRY	A02101	300-SFM-40A	MITSUBUSHI	1984	X110
TRANSFORMER BREAKER	330	1985	5T2A&5T2B TRFS PRY	A02184	300-SFM-40A	MITSUBUSHI	1984	X210
TRANSFORMER BREAKER	330	09-2013	5T4A TRF PRY	160041	362 SB6-2Y	MAGRINI GALILEO	2001	X410
TRANSFORMER BREAKER	330	2010	5T4B TRF PRY	160040	362 SB6-2Y	MAGRINI GALILEO	2001	X510
TRANSFORMER BREAKER	132	1982	5T1A SEC	HA1909511	ELF 145nc 1r	BBC	1982	410074
TRANSFORMER BREAKER	132	1982	5T1B SEC	HA1909521	HA145/C/R	BBC	1982	410054
TRANSFORMER BREAKER	132	2010	5T2A SEC	1HSB0844070	LTB 145D1/B	ABB	2008	410164
TRANSFORMER BREAKER	132	1982	5T2B SEC	HA1909516	ELF 145nc 1r	BBC	1982	410124
TRANSFORMER BREAKER	132	2010	5T4A SEC	6673-10-2031006/13	GL 312 F1	AREVA	2007	
TRANSFORMER BREAKER	132	2000	5T4B SEC	30464	FX 11	ALSTOM	1999	410174

ASSET DESCRIPTION	RATED VOLTAGE(KV)	DATE OF ACQUISITION/INSTALLATION	ASSET IDENTITY NO(NUMENCLATURE)	ASSET SERIAL NO	MODEL/CCT TYPE	NAME OF MANUFACTURER	MANUFACTURE DATE	ASSET CODE(NOMENCLATURE)
TRANSFORMER BREAKER	132	2010	10T1A PRY	1HSB0846025	LTB 145D 1/B	ABB	2009	410044
TRANSFORMER BREAKER	132	1982	10T2B PRY	1909513	HA14 5/C/R	BBC	1982	410104
TRANSFORMER BREAKER	132	2010	10T2A PRY	X302711	120-SFM-32B	ABB	2010	
FEEDER BREAKER	132	2002	IJORA LINE 1	159508	SB6 145	M/GALILEO	2001	410084
FEEDER BREAKER	132	N/A	IJORA LINE 2	N/A	N/A	N/A	N/A	410094
FEEDER BREAKER	132	2000	ISOLO LINE 1	30462		GEC ALSTOM	1999	410014
FEEDER BREAKER	132	2002	ISOLO LINE 2	159504	SB6 145	M/GALILEO	2001	B410034
FEEDER BREAKER	132	1982	ITIRE LINE 1	1909514	HA14 5/C/R	BBC	1982	B410154
FEEDER BREAKER	132	2000	ITIRE LINE 2	30463		GEC ALSTOM	1999	B410174
FEEDER BREAKER	132	1982	OJO LINE 1			ABB	1982	410132
FEEDER BREAKER	132	2002	OJO LINE 2	159509	SB6 145	M/GALILEO	2001	
BUSCOUPLER BREAKER	132	1982	BUS COUPLER	410008	HA14 5/C/R	BBC	1982	410008

Appendix H: Akangba T.S 33kv circuit breaker asset inventory

S/N	ASSET DESCRIPTION	RATED VOLTAGE(KV)	DATE OF ACQUISITION/INSTALLATION	ASSET SERIAL NO	MODEL/CCT TYPE	NAME OF MANUFACTURER	MANUFACTURE DATE	ASSET CODE
1	IGANMU FDR BREAKER	33						
2	ADELABU 1 FDR BREAKER	33		OHB 3119	OHB 36. 16. 32	ABB	2011	
3	SANYA FDR BREAKER	33		VBF 36. 20. 25	IVYN 03011100 0078	ABB		
4	60MVA,10T2A SEC BREAKER	33		OHB 36. 16 32	OHB 2742	ABB	2010	

S/N	ASSET DESCRIPTION	RATED VOLTAGE(KV)	DATE OF ACQUISITION/ INSTALLATION	ASSET SERIAL NO	MODEL/ CCT TYPE	NAME OF MANUFACTURER	MANUFACTURE DATE	ASSET CODE
5	AMUWO FDR BREAKER	33		OHB 2755	OHB 36. 16. 32	ABB	2010	
6	IDIARABA/LUTH FDR BREAKER	33	2012	IVYNO 301200272	OHB 36.12.32	ABB	2012	
7	IDIARABA/NRC FDR BREAKER	33	1968	602111970 Dm 7	DBG 725mc 150g	BBC	1968	
8	ADELABU 2 FDR BREAKER	33	2012	IVYNO 501312000 271	OHB 36.12.32	ABB	2012	
9	60MVA, 10T2A SEC BREAKER	33	2010	OHB 2742	OHB 36. 16. 32	ABB	2010	
8	60MVA, 10T1A SEC BREAKER	33	1968	602111970 Dm 9	DBG 725mc 150g	BBC	1968	
9	60MVA, 10T2B SEC BREAKER	33	2012	IVYNO 303120002 75	OHB 36.12.32	ABB	2012	210064