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Improvement of 33kv Overcurrent Protection Scheme for Effurun Transmission Substation at PTI Road, Delta State, Nigeria

Amakiri O. Friday[1], Engr. Prof D.C. Idoniboyeobu[2], Engr. Prof C.O. Ahiakwo[3], Engr. Dr S.L. Braide[4].
[1, 2, 3 & 4] *Department of Electrical Engineering, Rivers State University, Port-Harcourt Nigeria*
Corresponding Author: Amakiri O. F,

ABSTACT: *The research work is initiated to investigate Effurun 3x 60MVA, 132/33kV transmission substation network, because this network faced fire outbreak, power outage several times, and abnormal tripping of feeder during last couple of years. Using ETAP software as analytical tool, the network was drawn. The data for each component in the network was collected from a site visit. The simulator was ruined and different fault scenarios were created to analyse the existing overcurrent protection schemes and different miss-coordination or operations results were obtained as a response of protection system to the abnormal conditions. After studying this network, it was noticed that one of the main reasons for fire outbreak, outage of power and abnormal tripping of protection devices is the relay setting miss-coordination caused by the use of only definite minimum time (DMT) and grading by time overcurrent protection scheme. Inverse definite minimum time(IDMT) relay and grading by both Time current overcurrent protection scheme was chosen, and this scheme is modelled which starts first by coordinating three phase overcurrent elements, for different paths from furthest downstream up to the upstream. Next the instantaneous element as a backup protection as applied successfully. The new relay setting coordination has been applied to all relays in the Effurun substation as a result from this study. The sequence of operation is well improved and total outage of power, abnormal tripping of feeders is significantly reduced.*

Keywords*– definite minimum time (DMT), inverse definite minimum time (IDMT), grading by time, grading by both time and current, sequence of operation.*

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I. INTRODUCTION

In Nigeria, power systems are made of three divisions that are called a generation, transmission and distribution and is very complex in nature. Its operations and cost of maintaining is quite high. Hence, there is a requirement of adequate protection scheme against any fault for strong and reliable operation of power system. Therefore transmission and distribution feeders should be protected by comprehensive protection scheme [6]. Overcurrent protection schemes for power system has been developed to minimize damage and make sure supply is safe, continuous and economical. This is achieved by using overcurrent relays. An overcurrent relay is a device that make measurement or receives signals that causes it to operate and effect the operations of other equipment's. It responds to abnormal conditions in faulty section of the network with minimum interruption of supply [1]. Overcurrent relay coordination plays a vital role with overcurrent protection scheme. It is an integral part of the overall system of overcurrent protection and is absolutely necessary to isolate only the faulty circuit, prevent tripping of healthy circuit [3]. The overcurrent protection scheme designed for the network should be fast and selective. For a good protection scheme, a reliable backup should exist in case the primary protective system fails. [2]. Overcurrent protection scheme designed for the network should be fast and selective. For a good protection scheme, a reliable backup should exist in case the primary protective system fails. This backup protection should act as a backup either in the same station or in the neighboring lines with a time delay according to the selective requirement [5]. There should be a backup protection for which proper overcurrent relay setting and coordination is necessary. To coordinate the overcurrent protection, the backup relay must have enough time delay for the primary relay (and its breaker) to clear the fault (4).

II. PROBLEMS STATEMENT

There are numerous causes of fire outbreak and electrocution in our electricity transmission and distribution network in Nigeria, due to faults on our power station feeder's line, which resulted in shutting down of socio-economic activities of our society. Therefore a great deal of study and development of devices and design of overcurrent protection schemes have resulted in continual improvement in the prevention of damage to power equipment, transmission and distribution lines and to guarantee safety of life and property. Similarly, problems of inadequate selection of overcurrent protection schemes in our power stations led to system collapse, eventually the entire system. Without question, the associated problems which has led to:

i. Outage of power supply.
ii. Regular abnormal tripping of the protective devices.
iii. Permanent shorting down of power equipment due to fire outbreak.
iv. Short down of power lines.

III. MATERIALS AND METHODOLOGY

3.1 Materials: A site visit was conducted with Effurun 3x60MVA, 132/33kV Transmission Station P.T.I road Effurun Delta State. In order to collect the necessary data of the existing network, collect the uploading setting of the protection system and investigate the defects of the existing setting.

The following data was collected,

i. A one-line diagram of Effurun 3x60MVA, 132/33kV Transmission Substation P.T.I road Effurun Delta State, Nigeria. Were all the types and rating of the protection devices and their associated current transformers are shown.
ii. The impedance of all Transmission lines and Transformers.
iii. Load details (MVAR and MW) of the existing network.
iv. Length and type of Transmission lines from Effurun to other station.

The data collected is shown in appendix A and B respectively.

3.2 Methodology: The paper is to investigate Effurun 3x 60MVA, 132/33kV transmission substation network by using ETAP 16.0.0 software as analytical tools, in other to eliminate problems associated to fire outbreak, electrocution, regular abnormal tripping of protection devices etc. The simulator was ruined with the aid of the existing model (DMT) for different scenarios and was discover that one of the main reason for fire outbreak, abnormal tripping of protection devices and outage of power for Effurun Transmission Substation is the relay setting miss-coordination caused by the use of only definite minimum time (DMT) with grading by time overcurrent protection scheme. Base on this Inverse definite Minimum Time(IDMT) relay with grading by both Time current overcurrent protection scheme was chosen, and this scheme is modelled which starts first by coordinating the three phase overcurrent elements, for different paths from furthest downstream up to the upstream. Next the instantaneous element as a backup protection was applied successfully. The new relay setting coordination to applied to all relays in the Effurun substation as a result from this study.

Figure 1 shows Single line Diagram of Effurun Transmission Substation network,

The station consists of three (3) transformers which have capacity of 60MVA each and has seven (7) feeders, 33kV to Refinery I, 33kV to Refinery ii, 33kV to Warri, 33kV to Sapele, 33KV to P.T.I, 33kV to Effurun, 33kV to Enerhen. With the purpose of this paper, we are concentrating on the three (3) feeder, Refinery 1 33kV feeder, Refinery 11 33kV feeder and Enerhen 33kV feeder.

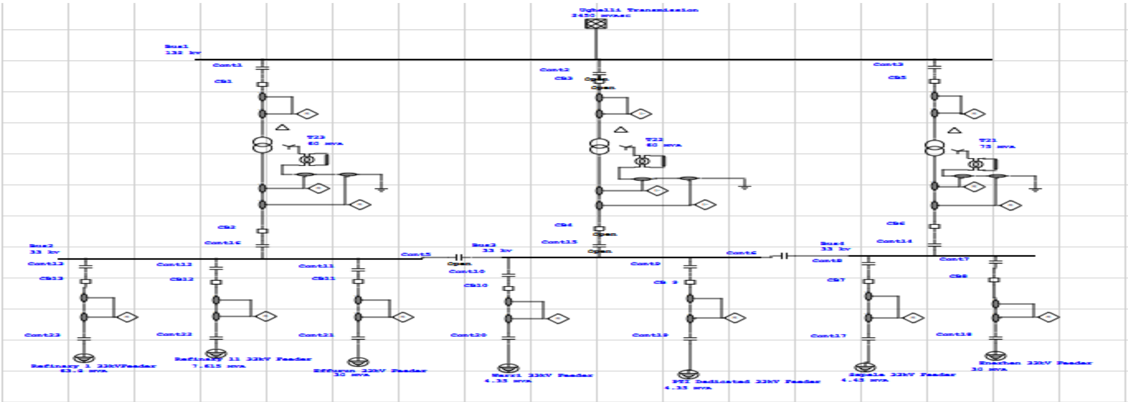

Figure 3.1 shows Single line Diagram of Effurun Transmission Substation network

3.3 Simulation Scenarios of the Existing Network of Effurun 3 X 60MVA, 132/33kv Substation Setting.

The existing scheme and setting of this substation all outgoing 33kV lines relay setting was DMT (time grading) with a time delay of 0.05sec and 0.1 sec with lead to the trip of the outgoing 33kV lines for any fault that occurs at the substation feeder. Hence the protection is miss-coordinated.

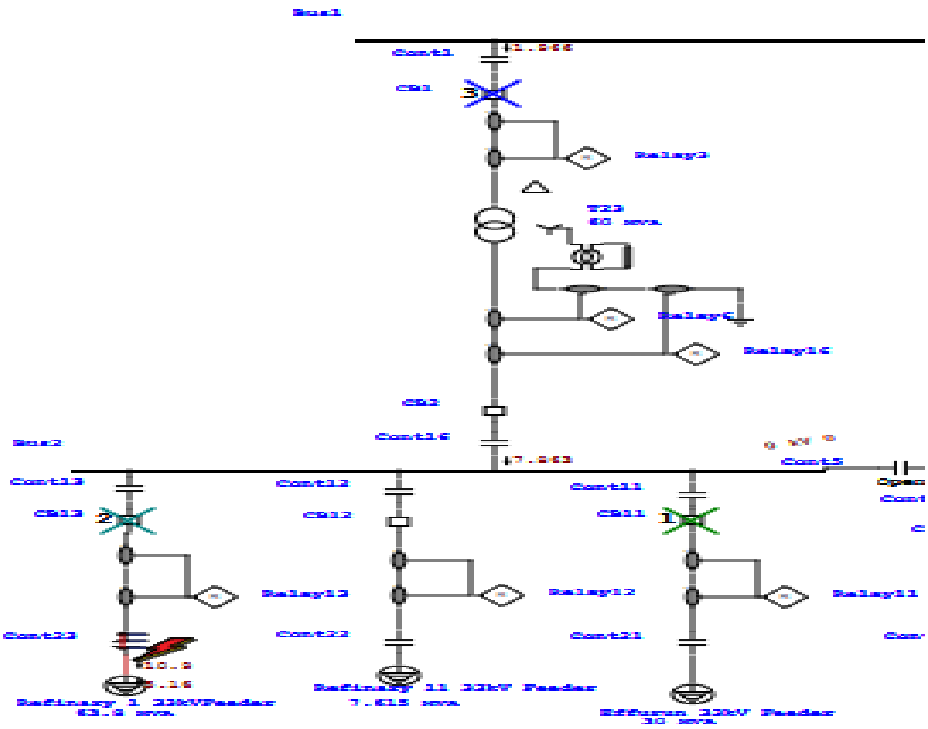

Figure 3.2 Three phase fault on Refinery 1 33kv feeder

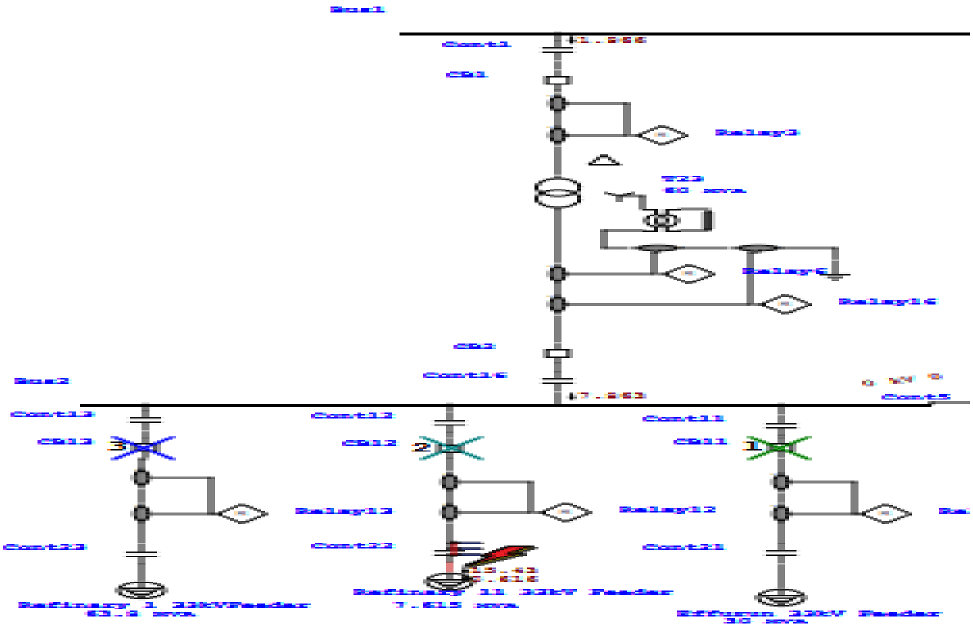

Figure 3.3 three phase fault for Refinery 11 33kV feeder

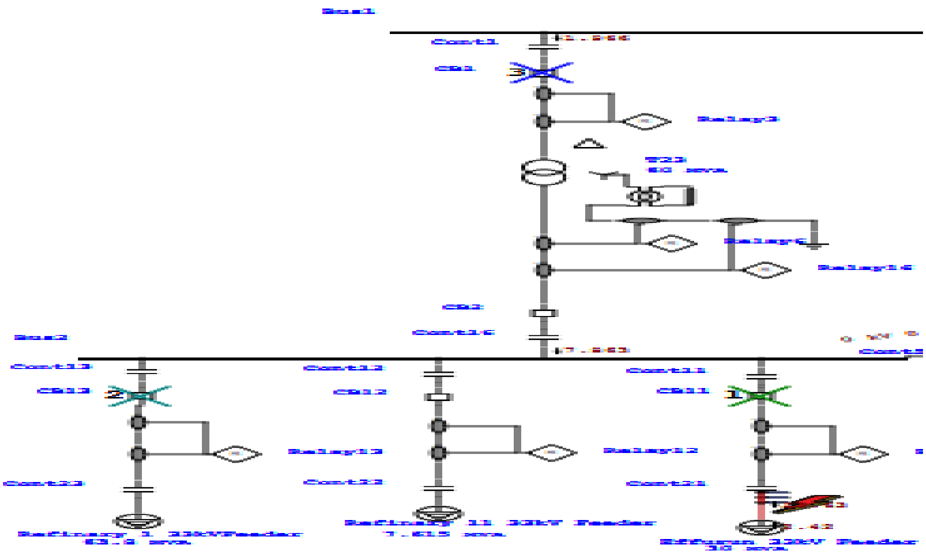

Figure 3.4 Three phase fault for Effurun 33kV feeder

3.4 New improved Overcurrent Setting of Effurun Transmission Substation

The coordination started from downstream at 33kV feeders to the upstream at 132kV incomer line, this coordination carryout by both current and time grading and IDMT relay to ensure adequate fault isolation. The coordination is shown in the next figures.

3.5 Standard Equation for overcurrent relay

Step 1, read within the existing data excessive and low voltages of the line, short circuit current primary and secondary current of high voltage current transformer (HV, CT), a primary and secondary current of low voltage current transformer (LV CT), time graded margin and time setting multiplier (TMS)

Step 2, calculate the relay current of relay 1 (I_{R1}) using equ (3.1)

$$I_{R1} = \frac{\text{Fault current}}{\text{CT ratio}} \qquad (3.1)$$

Steps 3, Calculate the pickup values of relay 1(P_{U1}) using equation (3.2)

$$P_{UI} = \frac{CS-RCS}{100} \quad (3.2)$$

CS = current setting

RCS =rated current of secondary CT

Steps 4, Calculate the plug setting multiplier (PSM) using equation (3.3)

$$PSM = \frac{I_{R1}}{P_{U1}} \quad (3.3)$$

Steps 5, Determine relay type (t) and calculate the time of operation using the following equation (3.4)

$$SIR = \frac{0.14}{PSM^{0.02} - 1} \quad (3.4)$$

SIR = Standard inverse relay

Steps 6, Calculate the actual operating time (T1) of the relay using equation (3.7)

$$T_1 = t \text{ x TMS} \quad (3.6)$$

Steps 7, Calculate fault current (IFR2) in relay 2 using equation (3.8)

$$T_{FR2} = \frac{\text{Fault current LV}}{\text{HV}} \quad (3.7)$$

Steps 8, Calculate fault current (IR2) in relay 2 using equation (3.9)

$$I_{R2} = \frac{I_{FR2}}{\text{Relay2 CT ratio}} \quad (3.8)$$

Steps 9, Calculate pickup current of relay 2 (PU2) using equation (3.10)

$$P_{U2} = \frac{C_S - R_{CS}}{100} \quad (3.9)$$

Steps 10, Calculate the plug setting multiplier of relay 2 (PSM2) using equation (3.11)

$$PSM = \frac{I_{R2}}{P_{U2}} \quad (3.10)$$

Steps 11, Determine the time of operation using step 4

Steps 12, Calculate the actual operating time of relay 2 (T2) using equation (3.12)

$$T_2 = t \text{ x TMS} + T_2 \quad (3.11)$$

3.6 Simulation Scenarios (New Setting)

Now when applying the new setting mentioned in above section in ETAP to simulate the sequence of operations for the same type of faults as mention in the existing case, the results showed that all the problems associated with the existing setting has been resolved and the network is well coordinated.

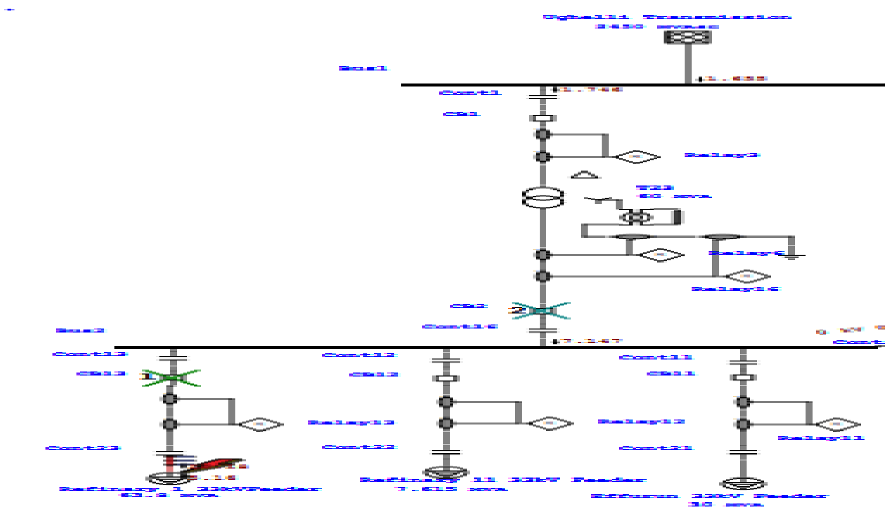

Figure 3.5 Three phase fault on Refinery 1 33kV feeder (New case)

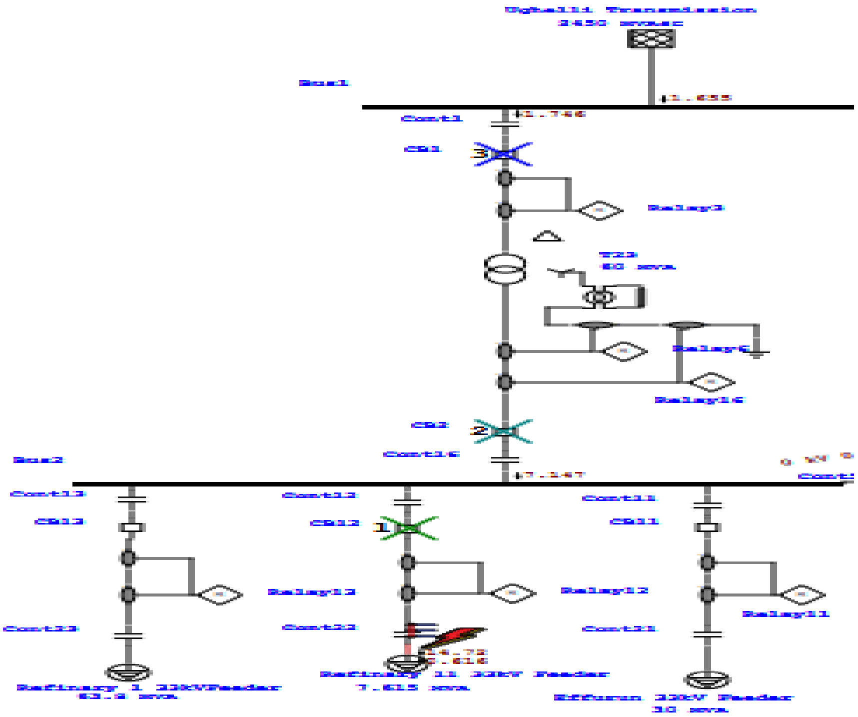

Figure 3.6 Three phase fault was simulated at Refinery 11 33kV feeder (New case)

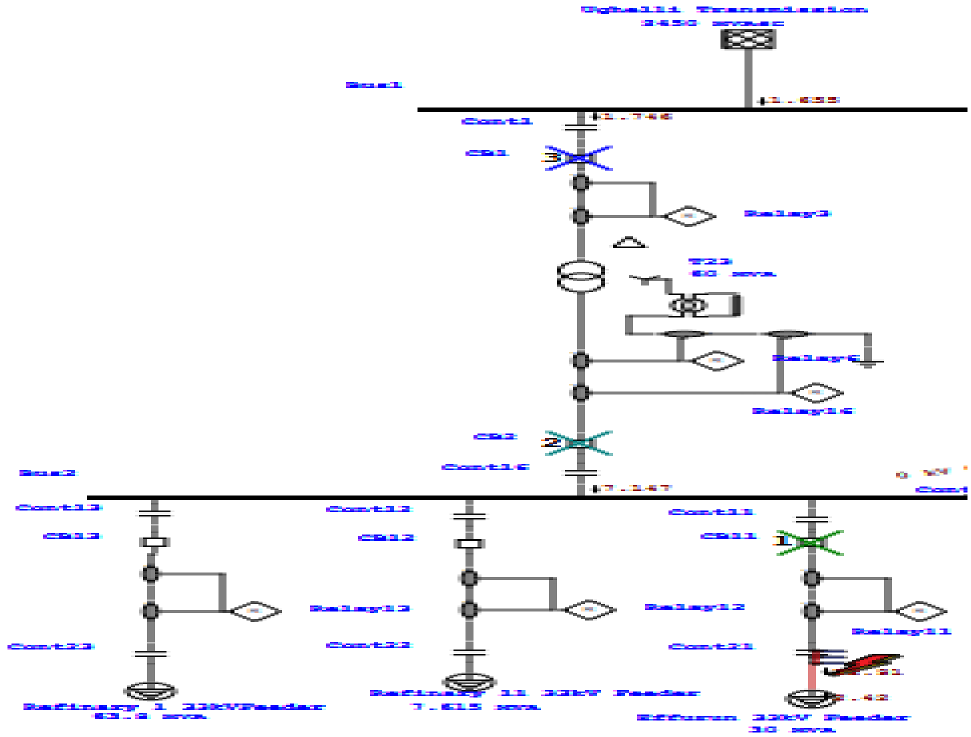

Figure 3.7 Three phase fault was simulated at Effurun 33kV feeder (New case)

IV. RESULT AND DISSCUSSION

4.1 Result Summary and Discussion of the existing case for Refinery 1 33kV feeder

The sequence of operation (tripping) that occurred due to the insertion of fault on **Refinery 1 33kV feeder**

(Figure 2) are summarized in Table 4.1.

Table 4.1 Sequence of operation for Refinery 1 33kV feeder

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Cont23 & Refinary 1 33kVFeeder. Adjacent bus: Bus2

Data Rev.: Base Config: Normal Date: 08-12-2018

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
50.0	Relay11	2.425	50.0		Phase - OC1 - 51
60.0	CB11		10.0		Tripped by Relay11 Phase - OC1 - 51
100	Relay13	10.896	100		Phase - OC1 - 50 (TOC blocked by IOC)
110	CB13		10.0		Tripped by Relay13 Phase - OC1 - 50 (TOC block...
250	Relay3	1.966	250		Phase - OC1 - 51
250	Relay6	7.863	250		Phase - OC1 - 51
250	Relay16	7.863	250		Phase - OC1 - 51
260	CB1		10.0		Tripped by Relay3 Phase - OC1 - 51
260	CB2		10.0		Tripped by Relay6 Phase - OC1 - 51

From table 4.1, it's clear that the feeder relay (relay 11) tripped before the faulted relay 13 and relays at the primary side of the transformers (relays 3) tripped at 250milliseconds , which means that for a single three phase fault at the downstream feeder will trip other downstream feeders.

The correct sequence of operation is that the feeder relay(relay 13) must first trip, followed by the secondary side of the transformer relay (relay 6) which is delayed by at least 150 millisecond after which the primary side of the transformer 132kV incomers (relay 3) will also be delayed by at least 150 millisecond before it trips.

4.2 Result Summary and Discussion of the existing case for Refinery 11 33kV feeder

The sequence of operation (tripping) that occurred due to the insertion of fault on Refinery 11 33kV feeder (Figure 3.3) are summarized in Tables 4.2.

Table 4.2 Sequence of operation for Refinery 11 33kV feeder

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Cont22 & Refinary 11 33kV Feeder. Adjacent bus: Bus2

Data Rev.: Base Config: Normal Date: 08-12-2018

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
50.0	Relay11	2.425	50.0		Phase - OC1 - 51
60.0	CB11		10.0		Tripped by Relay11 Phase - OC1 - 51
100	Relay12	15.433	100		Phase - OC1 - 50 (TOC blocked by IOC)
100	Relay13	5.157	100		Phase - OC1 - 50 (TOC blocked by IOC)
110	CB12		10.0		Tripped by Relay12 Phase - OC1 - 50 (TOC block...
110	CB13		10.0		Tripped by Relay13 Phase - OC1 - 50 (TOC block...
250	Relay3	1.966	250		Phase - OC1 - 51
250	Relay6	7.863	250		Phase - OC1 - 51
250	Relay16	7.863	250		Phase - OC1 - 51
260	CB1		10.0		Tripped by Relay3 Phase - OC1 - 51
260	CB2		10.0		Tripped by Relay6 Phase - OC1 - 51

From table 4.2, it's clear that the feeder relay (relay 11) tripped before the faulted relay (relay 12) and relays (relays 13) tripped at the same time , which means that the whole T23 incomer line is out for a single three phase fault at the downstream feeder.

The correct sequence of operation is that the feeder relay(relay 12) must first trip followed by the secondary side of the transformer relay (relay 6) delayed by at least 150 millisecond then the primary side of the transformer 132kV incomers (relay 3) also delayed by at least 150 millisecond.

4.3 Result Summary and Discussion of the existing case for Effurun 33kV Feeder

The sequence of operation (tripping) that occurred due to the insertion of fault on **Effurun 33kV Feeder** (Figure 3.4) are summarized in Table 4.3.

Table 4.3 Sequence of operation for Effurun 33kV feeder

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Cont21 & Effurun 33kV Feeder. Adjacent bus: Bus2

Data Rev.: Base Config: Normal Date: 08-12-2018

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
100	Relay11	13.625	100		Phase - OC1 - 50 (TOC blocked by IOC)
100	Relay13	5.157	100		Phase - OC1 - 50 (TOC blocked by IOC)
110	CB11		10.0		Tripped by Relay11 Phase - OC1 - 50 (TOC block...
110	CB13		10.0		Tripped by Relay13 Phase - OC1 - 50 (TOC block...
250	Relay3	1.966	250		Phase - OC1 - 51
250	Relay6	7.863	250		Phase - OC1 - 51
250	Relay16	7.863	250		Phase - OC1 - 51
260	CB1		10.0		Tripped by Relay3 Phase - OC1 - 51
260	CB2		10.0		Tripped by Relay6 Phase - OC1 - 51

From table 4.3, it's clear that the faulted feeder relay (relay 11) tripped before the adjacent relay (relay 12) and relays (relays 13) tripped at the same time , which means that for a single three phase fault at the downstream feeder will not affect the upstream T23 incomer line.

Another point on this analysis is that the feeder relay (relay 11 & 13) time overcurrent (TOC) is blocked by instantaneous overcurrent for its operation. Therefore the protection scheme is miss-coordinated.
The correct sequence of operation is that the feeder relay(relay 11) must first trip, followed by the secondary side of the transformer relay (relay 6) delayed by at least 150 millisecond then the primary side of the transformer 132kV incomers (relay 3) also delayed by at least 150 millisecond.

4.4 Result Summary and Discussion of the new case for Refinery 1 33kV feeder

The results obtained from the new relay coordination setting is shown in append C (Table C.2) The tripping that occurred due to the insertion of fault on **Refinery 1** 33kV feeder are (figure 3.5) summarized in Table 4.4.

Table 4.4 Sequence of operation for a three phase fault on Refinery 1 33kV feeder (New case)

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Cont23 & Refinary 1 33kVFeeder. Adjacent bus: Bus2

Data Rev.: Base Config: Normal Date: 27-12-2018

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
0.0	Relay13	10.185	0.0		Phase - OC1 - 50
10.0	CB13		10.0		Tripped by Relay13 Phase - OC1 - 50
215	Relay6	7.151	215		Phase - OC1 - 51
215	Relay16	7.151	215		Phase - OC1 - 51
225	CB2		10.0		Tripped by Relay6 Phase - OC1 - 51
382	Relay3	1.747	382		Phase - OC1 - 51
392	CB1		10.0		Tripped by Relay3 Phase - OC1 - 51
1561	Relay11	2.425	1561		Phase - OC1 - 51
1571	CB11		10.0		Tripped by Relay11 Phase - OC1 - 51

From table 4.4. It is clear that the feeder relay (relay 13) was tripped first at 0ms by instantaneous element followed by the incomer secondary relay (relay 6) delayed after 215 millisecond then the primary side of the transformer relay (relay 3) tripped after 382millisecond. Now this is the correct sequence of operation, also the grading margin between relays is maintained above 150 millisecond. Hence, miss-coordination will not occur as demonstrated in figure (3.5)
From above sequence of operation, the discrimination was conducted correctly which was not achieved at the existing setting as shown in figure (2).

4.5 Result Summary and Discussion of the new case for Refinery 11 33kV feeder

The results obtained from the new relay coordination setting is shown in append C (Table C.2) The tripping that occurred due to the insertion of fault on **Refinery 11** 33kV feeder (figure3. 6) are summarized in Table 4.5.

Table 4.5 Sequence of operation for a three phase fault on Refinery 11 33kV feeder (New case)

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Cont22 & Refinary 11 33kV Feeder. Adjacent bus: Bus2

Data Rev.: Base Config: Normal Date: 27-12-2018

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
0.0	Relay12	14.722	0.0		Phase - OC1 - 50
10.0	CB12		10.0		Tripped by Relay12 Phase - OC1 - 50
215	Relay6	7.151	215		Phase - OC1 - 51
215	Relay16	7.151	215		Phase - OC1 - 51
225	CB2		10.0		Tripped by Relay6 Phase - OC1 - 51
382	Relay3	1.747	382		Phase - OC1 - 51
392	CB1		10.0		Tripped by Relay3 Phase - OC1 - 51
637	Relay13	5.157	637		Phase - OC1 - 51
647	CB13		10.0		Tripped by Relay13 Phase - OC1 - 51
1561	Relay11	2.425	1561		Phase - OC1 - 51
1571	CB11		10.0		Tripped by Relay11 Phase - OC1 - 51

From table 4.5 It is clear that the faulted feeder relay (relay 12) was tripped first at 100ms by instantaneous element followed by the incomer secondary relay (relay 6) delayed after 250 millisecond then the primary side of the transformer relay (relay 3) tripped. Now this is the correct sequence of operation, also the grading margin between relays is maintained above 150 millisecond. Hence, miss-coordination will not occur as demonstrated in figure (3.6).

From above sequence of operation, the discrimination was conducted correctly which was not achieved at the existing setting as shown in figure (3.3).

4.6 Result Summary and Discussion of the new case for Effurun 33kV feeder

The results obtained from the existing relay coordination setting is shown in appendices C (Table C.2). The tripping that occurred due to the insertion of fault on Effurun 33kV feeder (figure 3.7) are summarized in Tables 4.6

Table 4.6 Sequence of operation for a three phase fault on Effurun 33kV feeder (New case)

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Symmetrical) fault on connector between Cont21 & Effurun 33kV Feeder. Adjacent bus: Bus2

Data Rev.: Base Config: Normal Date: 27-12-2018

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
0.0	Relay11	12.914	0.0		Phase - OC1 - 50
10.0	CB11		10.0		Tripped by Relay11 Phase - OC1 - 50
215	Relay6	7.151	215		Phase - OC1 - 51
215	Relay16	7.151	215		Phase - OC1 - 51
225	CB2		10.0		Tripped by Relay6 Phase - OC1 - 51
382	Relay3	1.747	382		Phase - OC1 - 51
392	CB1		10.0		Tripped by Relay3 Phase - OC1 - 51
637	Relay13	5.157	637		Phase - OC1 - 51
647	CB13		10.0		Tripped by Relay13 Phase - OC1 - 51

Comparing table 4.6 with that of chapter three (figure 3.4), it's clear that the correct sequence of operation is now achieved. Also the grading margin between relays is maintained above 150 millisecond.

From the above sequence of operation analysis, shows the benefits of using instantaneous current at the beginning of the faulted feeder line to isolate the faults on the line as quickly as possible. In this case, the instantaneous element enable relay 12 to trip the line at 0 milliseconds.

V. CONCLUSION

5.1 Conclusion

The overcurrent protection settings coordination has been achieved successfully, and the sequence of tripping starts at far downstream of the three (3) 33kV feeder relay with IDMT, then followed by the upstream of 33kV incomer relay and 132kV primary transformer relay. Furthermore, the pickup settings for overcurrent element were coordinated as main protection and instantaneous element was performed successfully as a back-up protection.

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Tables

Table A.1 Transformer Technical Data

Station Transformer	Station MVA	Primary Volt (KV)	Secondary Volt (KV)	Vector Group	Copper Loss KV	Iron Loss KV	Leakage impedance Xp/s%	X/R Ratio	Earth Grounding HV side Zp	Earth Grounding LV side Zs
T21 Transformer	60	132	33	YNd11	48.315	9.804	7.7	15.906	Reactor	-
T22 Transformer	60	132	33	YNd11	X	X	X	X	Reactor	-
T23 Transformer	60	132	33	YNd11	48.315	9.804	7.7	15.906	Reactor	-

Source: Benin Electricity Distribution Company (BEDC), Effurun 3 x 132/33kV Substation.

Table A.2 X/R Ratio for each Transformer Rated MVA and copper losses

Transformer	Number of Taps	Voltage Combination	Normal Tap	For maximum Tap position		For normal tap position		For minimum tap position	
				Primary Volt (KV)	Secondary volt (KV)	Primary volt (KV)	Secondary volt (KV)	Primary Volt (KV)	Secondary Volt (KV)
T21 Transformer	14	(134.5 ±2 ± 7.5) 33kV	9A	145.225	36.55	134.5	33	130.775	32.45
T22 Transformer	X	X	X	X	X	X	X	X	X
T23 Transformer	14	(134.5 ± 2± 7.5) 33kV	9A	145.225	33.55	134.5	33	130.77	32.45

Source: Benin Electricity Distribution Company (BEDC), Effurun 3 x 132/33kV Substation.

Table A.3 Transformer Line Data

S/N	From	To	Length Km	ACS R/ AAC Sqm	Line Characteristic				
					R1 (pu: %)	XI (pu :%)	Ro (pu :%)	BI (pu :%)	Bo (pu :%)
1	Effurun	Refinery 1	96	250	67.64	216.82	181.37	49.28	29.76
2	Effurun	Refinery 2	42	150	49.42	98.84	110.89	662.16	441.12
3	Effurun	Effurun	2	150	2.35	4.71	52.80	32.48	21.01

Source: Benin Electricity Distribution Company (BEDC), Effurun 3 x 132/33kV Substation.

Table B.1Existing case of the three (3) 33KV Feeder on Bus bar

Feeder	**Overcurrent protection(50/51)**						**Earth protection (50N/51N)**					**Relay Type**
	CT Ratio	**Delay Curve type**	**Current setting**	**Time setting**	**Instantaneous Protection (DMT)**	**Time**	**CT Ratio**	**Delay Curve type**	**Current setting**	**Time setting**	**Instantaneous Protection (DMT)**	**Time setting**
Refinery 1	400/1	DMT	1>1In	0.05	1>>10 In	0.1s	400/1	DMT	1>0.15Ie	0.15	Disabled	Siprotech 7SJ62
Refinery 11	800/1	DMT	1>1In	0.05	1>>10 In	0.1s	800/1	DMT	1>0.15Ie	0.15	Disabled	Siprotech 7SJ62
Effurun	800/1	DNT	1>1In	0.05	1>>10 In	0.1s	800/1	DMT	1>0.15Ie	0.15	Disabled	Siprotech 7SJ62

Source: Benin Electricity Distribution Company (BEDC), Effurun 3 x 132/33kV Substation.

Table B.2Existing Setting of 33KV Transformer Incomer Line

Feeder	Overcurrent protection(50/51)						Earth protection (50N/51N)						
	CT Ratio	Delay Curve type	Current Setting	Time setting	Instantaneous Protection (DMT)	Time	CT Ratio	Delay Curve type	Current setting	Time setting	Instantaneous Protection (DMT)	Time setting	Relay Type
T21 Transformer	1200/1	DMT	1>1In	0.25s	10	0.1s	600/1	DMT	1>0.2Ie	0.05	Disabled		Siprotech 7SJ62
T22 Transformer	X	X	X	X	10	0.1s	X	X	X	X			Siprotech 7SJ62
T23 Transformer	1200/1	DMT	1>1In	0.25s	10	0.1s	300/1	DMT	1>0.2Ie	0.05			

Source: Benin Electricity Distribution Company (BEDC), Effurun 3 x 132/33kV Substation.

Table C.3Existing Setting of 132KV Transformer Feeders

Feeder	Overcurrent protection(50/51)						Earth protection (50N/51N)						Relay Type
	CT Ratio	Delay Curve Type	Current Settings	Time setting	Instantaneous Protection IDMT	Time	CT Ratio	Delay Curve type	Current setting	Time setting	Instantaneous Protection IDMT	Time setting	
T21 Transformer	300/1	DMT	1>1 In	0.25s	10	0.2s	300/1	DMT	1>0.2Ie	0.05	Disabled		Siprotech 7SJ62
T22 Transformer	X	X	X	X	X	X	X	X	X	X			Siprotech 7SJ62
T23 Transformer	300/1	DMT	1>1 In	0.25s	10	0.22	300/1	DMT	1>0.2Ie	0.05			Siprotech 7SJ62

Source: Benin Electricity Distribution Company (BEDC), Effurun 3 x 132/33kV Substation

Table C.1 New Relay Setting on the three (3) 33kV Feeder Lines

Feeder	Overcurrent protection(50/51)						Earth protection (50N/51N)						Relay Type
	CT Ratio	Delay Curve type	Current setting	Time setting	Instantaneous Protection IDMT	Time	CT Ratio	Delay Curve type	Current setting	Time setting	Instantaneous Protection IDMT	Time setting	
Refinery 1	400/1	IDMT	1> 1In	0.2	1>>10In	0s	400/1	IDMT	1>0.15Ie	0.15	Disabled		Siprotech 7SJ801
Refinery 11	800/1	IDMT	1> 1In	0.05	1>>5In	0s	800/1	IDMT	1>0.15Ie	0.15	Disabled		Siprotech 7SJ62
Effurun	800/1	1DNT	1> 1	0.25	1>>8In	0s	800/1	IDMT	1>0.15Ie	0.15	Disabled		Siprotech 7SJ62

Table C.2 New Relay Setting on the 33kV Transformer Secondary

Feeder	**Overcurrent protection(50/51)**						**Earth protection (50N/51N)**						**Relay Type**
	CT Ratio	**Delay Curve Type**	**Current Settings**	**Time setting**	**Instantaneous Protection IDMT**	**Time**	**CT Ratio**	**Delay Curve type**	**Current setting**	**Time setting**	**Instantaneous Protection IDMT**	**Time setting**	
T21 Transformer Secondary	1200/1	IDMT	1>1.2 In	0.05s	8	0.1s	600/1	IDMT	1> 0.2 Ie	0.05	Disabled		Siprotech 7SJ62
T22 Transformer	X	X	X	X	X	X	X	X	X	X			Siprotech 7SJ62
T23 Transformer	1200/1	IDMT	1>1.2 In	0.25s	10	0.2	600/1	IDMT	1> 0.2 Ie	0.05			Siprotech 7SJ62