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Effect of Electrical Power line length on Faults occurrences in Electrical Distribution System-A case study of Ayede 132/33kV substation

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Abstract: The paper examined the state of distribution network and analyzed the main causes of faults using Ayede 132/33kV as a case study. At the time of the study, the state of the major electrical facilities for 33kV distribution system was assessed to exploit information available related with the causes of faults. In addition, frequencies of faults occurrences on the feeders emanated from the substation as well as their lengths were obtained and were compared to know the effect of length of feeder on number of fault occurrence. In view of the findings during the cause of investigation, it is evident that the physical equipment needs urgent rehabilitation. Likewise, lengths of some feeders are too long compared to the magnitude of power they are transporting and required higher voltages for transmission.

Keywords: Distribution, Faults, Feeder, Transmission

I. INTRODUCTION

Electrical energy is an important form of energy, it is widely used by industries and companies and domestic purposes due to its easy control, transportation and cleanness. The social and economic development of the globe/ country/state is mostly affected by the availability of electrical power energy. Today, Nigeria as a country lacks adequate supply of electrical energy and there is continuing deterioration in the supply of electrical power in most part of the country. During normal operation, electrical power supply parameters: voltages and currents are within the nominal values. Whenever fault occurs, excessive current flows and causes damages to equipment and injuries to personnel [1]. Failures may occur somewhere in the system especially in transmission and distribution lines because power lines are widely branched, have greater length, operating at different weather conditions and are subjected to various actions of atmospheric discharges [2].

It is pertinent to examine the causes of power outages in most of our communities. In view of the fore mentioned, this research work wishes to identify major problems working against stable, reliable and good quality of electric power supply in Nigeria as well as proffering solutions and suggestions where necessary. This will improve the socioeconomic life of the Ibadan Electricity Distribution Company (IBEDC)'s customers in the area under investigation. The case study in this work is Ayede 132/33kV substation in Ibadan, the capital of Oyo state Nigeria.

II. REVIEW OF PREVIOUS WORKS

Various research works were done on faults studies, few research works were reviewed as follows: [3] Analyzed voltage sag distribution because of power system fault. Electrical fault is the main cause of voltage sag. Voltage sags were characterized by sag magnitude, duration, and frequency. [4] Made comparison between two methods of fault-location in distribution networks. They compared their performances. Results showed different drawbacks and advantages. [5] Presented a paper on the calculation of complex short circuit faults, aimed to help new protection engineers analyzed complex system faults and system operating conditions. The paper made use of symmetrical components for short-circuit analysis and provided the protection engineer with information for calculating proper relay settings for investigating relay operations that cannot be studied using typical short-circuit or load-flow programs. [6] Employed the influence of distributed generation method to analyze faults in power distribution system. The behavior of most significant parameters in power distribution systems: voltages, currents and apparent impedances at the substations were studied. It was discovered that they were affected by the values of fault resistance, the power supplied by DG and the relative location of DG and the fault. Different analyses are performed by varying DG locations and the fault. The presence of DG in a power distribution system decreases in value of apparent reactance shown in main substation. Thus, the estimate locations calculated by using impedance-based fault location methodologies will be closer than the actual location of the fault. [7] Presented system analysis with mega volts ampere (MVA) method for symmetrical three phase faults to determine system fault voltages and currents. Author highlighted the causes of faults: insulation failure, (a conducting material meets a bare conductor), lightning, and trees falling on the electric wires, vehicular collision with the poles or towers. Mega-volts-ampere (MVA) was offered to analyze faults in the system, and the results compared with two other methods: Ohmic conversion and Per-Unit conversion methods. MVA method was easier and recommended for power system short circuit calculations.

[8] Developed an algorithm that distinguished between short circuit fault current and overload current. Fault detection algorithm was adopted to detect the fault current and differentiate between fault current and overload current. The model performed excellently. [9] performed a fault analysis 33kV distribution network in Ekiti state, available data and electrical facilities were assessed and power availability in the substation was performed. The results showed poor supply of electricity to the feeder. [10] Designed a reclosing mechanism for permanent or temporary fault. The Timer Integrated circuit IC-555 was used to give the time duration of fault. Circuit breaker was used for disconnecting the line at fault instant and connecting on clearance of fault. Reclosing mechanism resets the supply line after small interruption in the event of temporary fault, but it remained in tripped condition in case of permanent fault. MATLAB software was used to simulate the system. Ideal switch related to signal builder, when signal was given to the switch, it closed, and fault occurred in the system and that instant circuit breaker is operated and disconnected the system from faulty part. Unbalances voltages were observed by closing the fault switch in Simu-link model. The faults were taken temporary as well as permanent. [11] Developed a Microcontroller-based protection for electric distribution system for the purpose of effective monitoring and control of distribution system. It consisted of GSM module, designed to send data from distribution network to the sub-station as well as recognizing the status of the network, whether safe or unsafe.[12] Evaluated fault voltage and current in a symmetric power system network. Newton-Raphson load flow was used to perform load flow analysis and IEEE 30 bus was used for simulation. Results obtained were used to determine size and type of protective system to be installed to ensure continuity of supply.[13] Examined electrical fault effect on the stability of a power system. Different causes of fault were highlighted as well as the effects on the system. IEEE 14bus was employed to analyze the effects. The results showed that if a fault at any section is left un-cleared or un-disconnected, it will result to huge crisis (total collapse).

In [14], a smart Global System for Mobile Communications (GSM) for accurate detection and location of faults has been provided. The unit provides a short time response for technical crew to rectify faults. Hence, save transformer and other equipment from damaging. Therefore, improve system stability.

III. MATERIALS AND METHOD

Historical Background of Ayede 132/33kV Substation

Ayede 132/33kV Sub-station is in the Transmission Company of Nigeria (TCN) yard at Ayede regional Transmission station. The yard housed two substations, namely:

(i) 330/132kV Transmission Substation
(ii) (ii) 132/33kV Transmission Substation

Ayede 132/33kV Substation receives 132kV electrical supply from Ayede 330/132kV. Transmission station and stepped it down to 33kV. Eight injection sub-stations take their sources from the secondary side if 132/33kV power transformers. These feeders include:

a) Apata feeder
b) Eleyele feeder
c) Express feeder
d) Interchange feeder
e) Iyanganku feeder
f) Lanlate feeder
g) Liberty feeder
h) Oluyole feeder

Data Collection

33kV feeders emanated from Ayede 132/33kV substation were inspected for on–the-spot assessment of the equipment and facilities installed. [15] was considered, forced outage readings of each feeder were taken. Daily faults occurrences on the substation were extracted. Table 1 contained the lengths of various feeders taking their sources from Ayede 132/33kV sub-station and Figure 1 showed the schematic diagram of Ayede 132/33kV sub-station

Table 1: Length of various feeders attached to Ayede 132/33kV Transmission substation.

S/N	Name of the Feeder	Length of the Feeder (km)
1	Apata	7.6
2	Eleyele	59.98
3	Express	10.6
4	Interchange	36
5	Iyaganku	2.8
6	Lanlate	192
7	Liberty	35
8	Oluyole	7.8

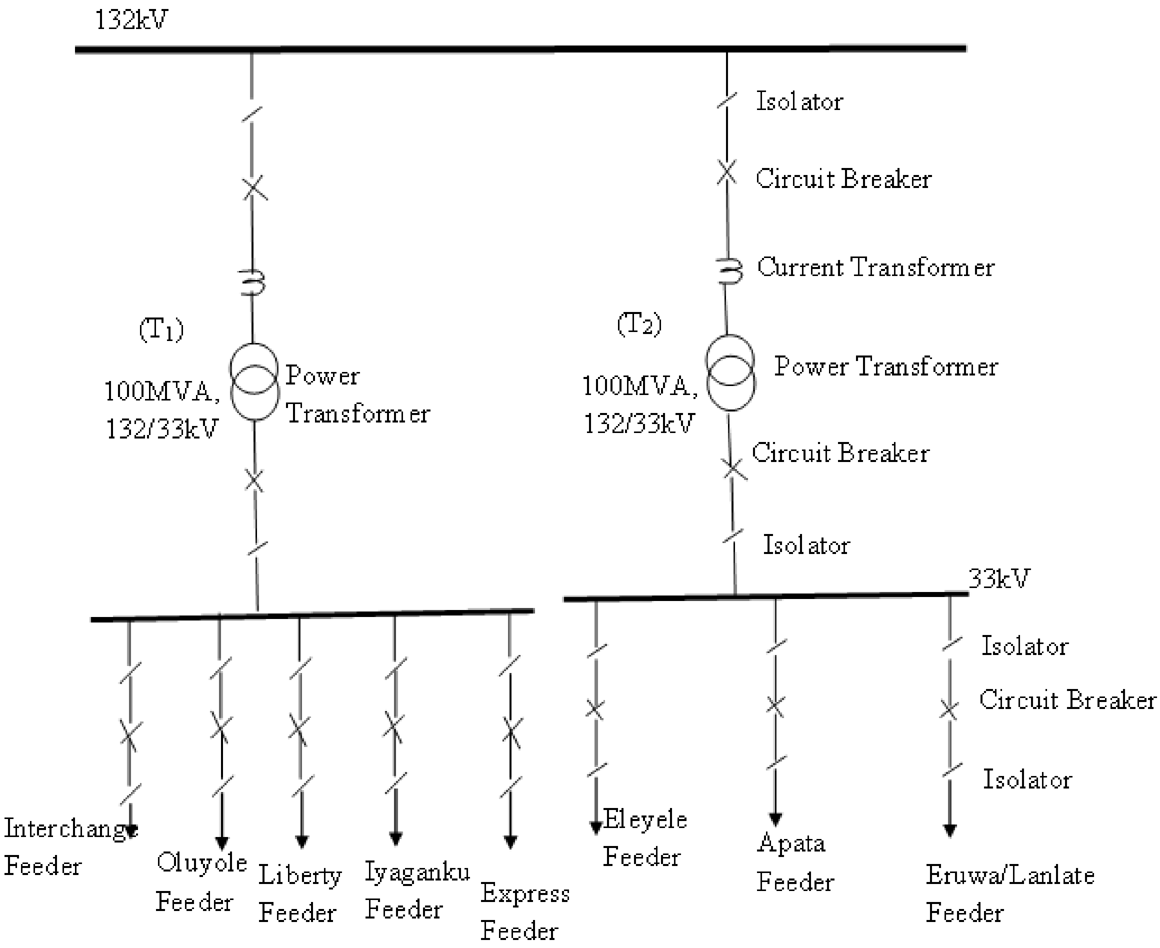

Figure 1 Schematic Diagram of Ayede 132/33kV Sub-station

III RESEARCH METHODOLOGY

In analyzing the fault in Ayede 132/33kV substation and feeders emanated from the substation, examining of the physical condition of the distribution system with reference to the pole supports, spans and clearances, types and size of conductors, cross-arms, type of insulators and route length is important. Tables 2 to 9 show details of feeders' route.

Table 2: Details of Apata Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		The line is routed within the city	The route is cleared
Sag			About 70% of the span met standard requirement	Improper construction and damaged cross arms are the causes
Distance		7.6km	Almost all the route length is cleared	The maintenance of the line is fair
Conductor	Aluminum ($100mm^2$)	22,800m	Loose strands were present	This is due to overheating resulting from overloading.
Sample Poles	Concrete	190	Few poles were defective	This is due to traffic accidents and poor erection.
Insulators	Pin insulator Disc insulator	504 132	Some insulators were defective	This is due to weather condition and aging.
Cross Arms	Wooden & Steel	178	Few cross arms were defective	Wooden cross arm is rotten and broken due to aging and exposure to rainfall and sunlight.

Table 3: Details of Eleyele Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		The line is located within the city	The line is cleared
Sag			About 60% of the span met standard requirement	This is due to construction error and damaged cross arms
Distance		59.98km	The route is cleared	Fairly maintained
Conductor	Aluminum ($100mm^2$)	179940m	Loose strands were noticed	installation defect and overheating suspected
Sample Poles	Concrete and steel	1510	Some poles were defective	This is due to improper erection of the poles
Insulators	Pin & Disc insulator	3468 1062	some insulators were Cracked	This is due to weather effects and aging
Cross Arms	Wooden and steel	1333	Few of the cross arms were defective	The wooden cross arms were rotten due to old age and exposure to atmospheric conditions

Table 4: Details of Express Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		The line routed within the city	The route is cleared
Sag			About 80% of the span met standard requirement	Effects of damaged wooden cross arms and improper erection of poles.
Distance		10.6km	The line is cleared	This is due to inadequate IBDEC staff
Conductor	Alluminiun ($100mm^2$)	31800m	Loose strands were present	This is due to expansion of conductor due to overloading
Sample Poles	Concrete	266	Defective poles were noticed	These were due to traffic accidents and poor erection
Insulators	Pin & Disc insulator	618 180	Defective insulators were observed	Rotten cross arm were observed
Cross Arms	Wooden &Steel	236	Few of the cross arms are defective	This is due to their exposure to rainfall and sunlight and aging.

Table 5: Details of Interchange Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		Line within ibadan	The route is cleared
Sag			About 65% of the span met standard requirement	Damaged cross arms, insulators and aging of the installation were observed.
Distance		34km	The route were cleared	Line routed within the Ibadan
Conductor	Alluminiun ($100mm^2$)	102,000m	Loose strands were present	Loosed strands were caused by overloading and aging of the installation
Sample Poles	Concrete	858	Some poles were defective	The defects are due to poor erection of poles, and vandalism by traffic accidents
Insulators	Pin insulator Disc insulator	1962 612	Some insulators were defective	This is due to rotten and broken cross arms and aged/ cracked insulators
Cross Arms	Wooden and steel	756	Some cross arms were defective	Some wooden cross arms are rotten and broken due to aging and exposure to atmospheric conditions.

Table 6: Details of Iyaganku Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		The line routed through the city	The route is cleared
Sag			About 80% of the span met standard requirement	Fair construction is likely the cause
Distance		2.8km	The line is neat	The line adequately maintained
Conductor	Alluminiun ($100mm^2$)	8,400m	Few strands were noticed.	Strands are due to overloading and installation error
Sample Poles	Concrete	72	Few poles were defective	This is due to errection error

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Insulators	Pin & Disc insulator	162 54	Insulators are okay	Good insulators
Cross Arms	Steel	63	Cross arms are okay	Good cross arms

Table 7: Details of Lanlate Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		Line passed through forest reserve	Part of the route is not easily accessible and not cleared
Sag			About 65% of the span met standard requirement	Damaged cross arms, insulators and aging of the installation
Distance		192km	Only few lengths of the route were cleared	This is due to negligence from IBEDC due to inadequate staffing. Feeder is long.
Conductor	Aluminum ($100mm^2$)	576km	Loose strands were present	The loose strands are the outcome of overloading and aging of the line.
Sample Poles	Concrete and wooden	3845	Poles were defective. Especially from Eruwa-Igboora	The defects are due to poor erection of poles, and vandalism by trees during rainfall
Insulators	Pin & Disc insulators Insulator	8535 2724	Some insulators were defective	Rotten and broken cross arms and aged/ cracked insulators
Cross Arms	Steel and wooden	3232	Some cross arms were defective	Some wooden cross arms are rotten and broken due to aging and exposure to atmospheric conditions.

Table 8: Details of Liberty Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		The line routed within the city	The route is cleared
Sag			About 80% of the span met standard requirement	Damaged wooden cross arms and improper erection of poles were observed
Distance		35.95km	The line is cleared.	This is due to inadequate IBDEC staff
Conductor	Aluminum ($100mm^2$)	107.8km	Loose strands were present	Expansion of conductor due to overloading
Sample Poles	Concrete	907	Defective poles were noticed	These were due to traffic accidents and poor errection
Insulators	Pin insulator Disc insulator	2073 648	Some insulators were defective	Insulators were affected due to rotten cross arm and atmospheric discharge e.g lightning
Cross Arms	Steel and wooden	799	Few of the cross arms are defective too	This is due to their exposure to rainfall and sunlight and aging.

Table 9: Details of Oluyole Feeder Route.

Item	Description	Quantity	Condition	Remarks
Line	33kV		The line routed through the city	The route is cleared
Sag			About 80% of the span met standard requirement	Fair construction is likely the cause
Distance		7.8km	The line is neat	The line is adequately maintained
Conductor	Aluminum ($100mm^2$)	23,400m	The conductors are okayed but few strands were noticed	The strands are due to overloading and installation error
Sample Poles	Concrete	198	Few poles were defective	This is due to erection error
Insulators	Pin & Disc insulator	450 144	Insulators are okay	Good insulators
Cross Arms	Steel	174	Cross arms are okay	Good cross arms

Monthly fault occurrence readings of each feeder for seven years (2015 to 2021) were shown in Tables 10 to 17.

Table 10: Faults Frequency for Apata Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	4	6	20	21	20	9	21
FEB.	5	8	14	15	14	12	15
MAR.	15	30	9	10	9	15	10
APR.	0	17	3	4.	3	20	14
MAY	15	5	11	12	11	14	12
JUN.	19	12	4	5	4	19	5
JUL.	5	13	30	24	30	31	31
AUG.	14	24	33	22	33	24	34
SEP.	5	13	15	24	15	9	16
OCT.	22	10	17	34	17	10	18
NOV.	14	11	22	23	22	21	23
DEC.	3	9	18	19	18	19	19

Table 11: Faults Frequency for Eleyele Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	24	5	25	5	7	5	5
FEB.	16	10	28	10	13	11	12
MAR.	4	14	29	14	26	15	39
APR.	0	10	17	10	10	11	10
MAY	1	13	28	13	13	14	12
JUN.	36	8	30	8	8	8	8
JUL.	16	16	24	16	16	17	16
AUG.	24	31	26	31	31	32	31
SEP.	17	42	27	42	42	43	42
OCT.	34	40	23	40	40	40	40
NOV.	24	39	29	39	26	40	39
DEC.	24	23	37	23	23	24	34

Table 12: Faults Frequency for Express Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	1	7	15	12	17	21	16
FEB.	8	15	12	15	15	15	26
MAR.	9	23	20	12	14	23	21
APR.	0	8	16	6	8	8	17
MAY	9	9	28	10	9	9	18
JUN.	12	18	14	13	18	18	15
JUL.	10	20	9	15	20	20	10
AUG.	14	11	18	15	11	11	19
SEP.	4	20	34	25	32	20	35
OCT.	11	31	33	21	31	32	34
NOV.	14	23	29	26	23	25	30
DEC.	1	15	25	15	15	18	26

Table 13: Faults Frequency for Interchange Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	13	2	27	17	15	14	28
FEB.	12	30	22	83	31	13	23
MAR.	8	28	34	35	29	29	35
APR.	10	22	27	28	15	31	28
MAY	8	11	33	34	12	28	34
JUN.	28	12	40	41	13	29	24
JUL.	15	18	26	27	19	16	27
AUG.	30	26	27	28	15	31	28
SEP.	15	24	28	29	25	16	29
OCT.	23	27	13	14	28	28	14
NOV.	29	23	14	15	24	22	15
DEC.	12	17	15	16	18	17	26

Table 14: Faults Frequency for Iyaganku Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	4	0	0	2	5	3	4
FEB.	3	0	1	2	6	3	6
MAR.	6	1	0	3	5	3	4

APR.	0	2	2	1	2	3	3
MAY	6	1	1	3	6	3	6
JUN.	6	1	1	2	6	3	4
JUL.	3	2	0	3	5	5	4
AUG.	0	3	1	2	6	5	6
SEP.	9	3	1	3	6	5	6
OCT.	6	1	1	3	6	3	4
NOV.	0	3	0	2	5	3	4
DEC.	4	1	0	2	5	3	4

Table 15: Faults Frequency for Eruwa/Lanlate Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	28	9	25	29	25	21	15
FEB.	26	19	55	39	45	44	18
MAR.	21	26	49	36	49	22	27
APR.	0	15	54	15	54	16	18
MAY	21	17	56	17	56	22	19
JUN.	30	12	59	12	59	31	24
JUL.	27	25	62	25	62	28	26
AUG.	50	31	36	32	36	51	32
SEP.	18	37	42	37	42	19	38
OCT.	30	13	55	23	55	31	18
NOV.	50	36	45	36	45	51	37
DEC.	32	24	48	24	48	33	25

Table 16: Faults Frequency for Liberty Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	4	6	16	15	17	17	15
FEB.	13	15	14	17	15	18	14
MAR.	14	24	11	13	12	12	15
APR.	6	12	9	10	10	23	14
MAY	14	12	22	14	23	23	15
JUN.	22	16	14	17	15	15	14
JUL.	2	15	19	15	20	18	16
AUG.	5	22	23	15	24	24	17
SEP.	12	24	21	13	22	12	19
OCT.	20	13	9	12	10	13	14
NOV.	5	13	14	12	15	13	14
DEC.	4	5	21	4	22	22	19

Table 17: Faults Frequency for Oluyole Feeder

	2015	2016	2017	2018	2019	2020	2021
JAN.	10	2	13	12	10	8	6
FEB.	5	18	10	18	6	12	16
MAR.	6	12	18	13	9	13	8
APR.	3	4	14	5	6	6	8
MAY	6	4	18	5	7	8	8
JUN.	4	2	16	3	6	8	9
JUL.	3	6	21	7	9	8	8
AUG.	5	0	12	12	16	12	8
SEP.	9	0	16	12	10	8	5
OCT.	2	0	16	6	8	9	10
NOV.	5	0	11	8	6	8	6
DEC.	10	6	18	8	9	6	8

IV. RESULTS AND DISCUSSION

Table 18 showed the summary of yearly faults occurrences and length of each feeder. Figure 2 showed graphical representations of relationship between feeders' lengths and the frequency of faults in each year. Table 18 showed that the number of faults occurrences increases as the length increases. Eruwa/Lanlate feeder is the longest feeder (192km), followed by Eleyele feeder (59.98km), Interchange feeder (36km) and Liberty feeder (35km) to mention few. In 2015, Eruwa feeder recorded 333 numbers of faults occurrences and Eleyele, Interchange and Liberty recorded 220, 203 and 120 numbers of faults respectively. In 2017, Eruwa, Eleyele, Interchange and Liberty had 586, 323, 306 and 193 numbers of faults respectively. In 2020 and 2021, the number of faults occurrences on Eruwa, Eleyele, Interchange and Liberty are 349, 260, 274 and 210 as well as 305, 288, 268 and 186 respectively.

Table 18: Summary ofyearly faultsOccurrences and feeders' length.

Feeder Name	Feeder Length (km)	Frequency of fault Occurrences						
		2015	2016	2017	2018	2019	2020	2021
Apata	7.6	121	158	196	213	196	203	218
Eleyele	59.98	220	251	323	251	255	260	288
Express	10.6	93	200	253	185	213	220	267
Interchange	36	203	240	306	307	244	274	268
Iyaganku	2.8	47	18	8	28	63	42	55
Eruwa/ Lanlate	192	333	264	586	325	576	349	305
Liberty	35	121	177	193	157	205	210	186
Oluyole	7.8	68	54	183	98	102	104	100

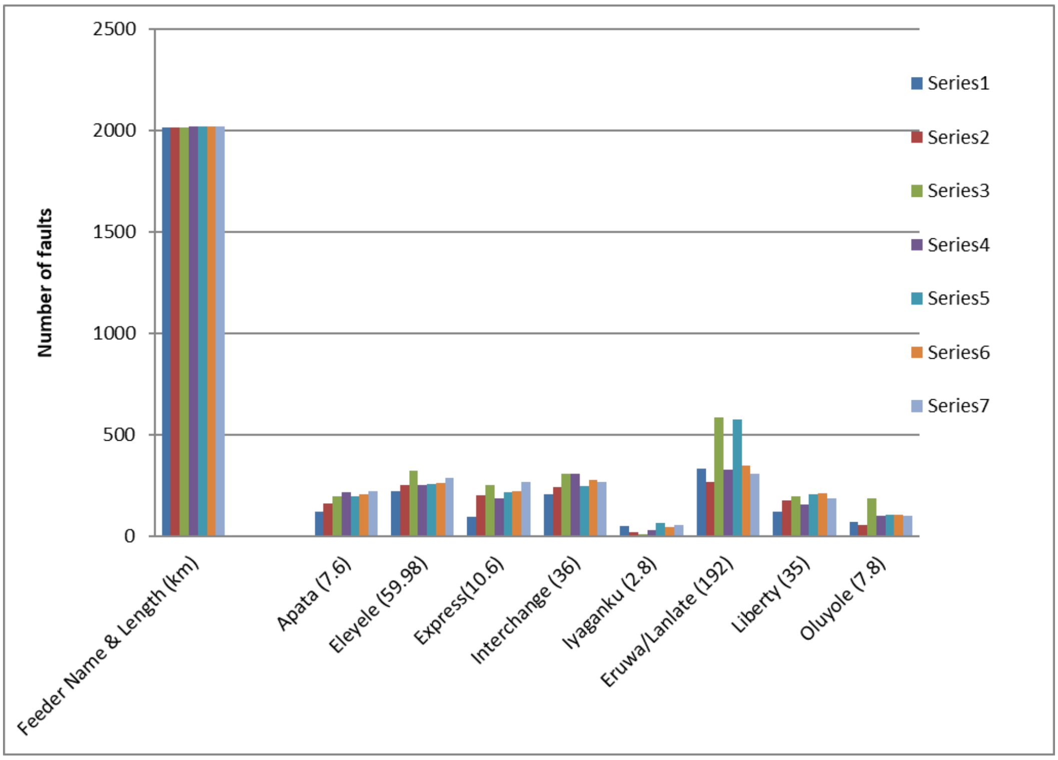

Figure 2: Comparison of feeders' length and yearly fault frequency

V. CONCLUSION AND RECOMMENDATIONS

The longest feeder recorded highest number of faults occurrences and the shortest feeder recorded the lowest number of fault occurrences. This implies that the number of faults occurrences is directly proportional to the feeder's length. Based on the results obtained in this work, the following are recommended.

i. All wooden poles and wooden cross-arm should be replaced with concrete poles and steel cross-arms respectively.

ii. The energy provider should be creative enough to see the effects of faults and its economic value in the sub-station and be innovative in their approach so as to reduce the losses.

iii. Where feeders are too long, e.g., Eruwa/Lanlate feeder, use of FACT devices should be encouraged.

iv. Constant clearing of the "right-of-ways" in Ayede 132/33kV sub-station feeders.

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Ethical statement: We declare that we have followed ethical responsibilities.

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