



FAULTS ANALYSIS OF 33KV ELECTRICITY DISTRIBUTION SYSTEM IN THE ABEOKUTA BUSINESS HUB

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ABSTRACT

This research work investigated the faults analysis usually encountered on a 33kv distribution system using the Abeokuta business hub in Ogun state, Nigeria as a case study. The available data which was analyzed statistically revealed that the bad condition of the physical structure of the 33kv distribution network was the major cause of frequent outage in Abeokuta and its environs. Accordingly, the deplorable state of the physical structure triggers most technical faults such as, short circuits, over-voltage etc. In this research work, different electrical faults were also studied, taking cognizance of the causes and how they hinder power supply to various consumers in Abeokuta city. Important components such as the feeders, distributors and the aluminium conductors of the 33kv distribution network were assessed. The study was extended to the 33/11kv distribution system and effects of faults on this system were also statistically analyzed. The data collected indicated that the power available in Abeokuta was approximately 32 percent of the total load demand, and the poor state of some feeders, insulators, and other facilities, hindered the efficient supply of the available power. The results also revealed that the 132kv lines (Aluminium conductors) are weak to carry the power required (about 85MW) in Abeokuta. Convincingly, it can be deduced that the physical structures and feeders of the 33kv distribution network in the Abeokuta business hub needs to be rehabilitated. In addition, a better maintenance management of the substations and their components is required to ensure better delivery of the available power to consumers at the real time.

Keywords: *Feeders, Short-circuits, Earth Fault, Distribution, Network.*

INTRODUCTION

Power distribution value chain system commences from generation, transmission, and distribution to the final consumers at different voltage levels (Uwaifo, 1994). Distribution voltages are achieved by stepping down the transmission voltages (330KV and 132KV) by a step-down power transformer in a substation. The 330KV is stepped down to 132KV which is further stepped-down to 33KV for the consumption of mostly industrial consumers and few proposed for developing areas (Burke, 1994).

In this study, a distribution system of 33KV voltage level is being considered. As earlier stated, 33KV is achieved by stepping-down 132KV using a 132/33KV step-down power transformer (Burke, 1994). This electrical activity is carried out in a substation which comprises of various electrical equipments such as breakers, relays, insulators, isolators, ground and switching systems before it is successfully achieved, and ready for consumption. At 33KV, electricity distribution is done by considering some basic safety measures to prevent total breakdown of the system and to reduce unavoidable faults on the grid.

An electrical fault can simply be defined as an abnormal condition of the power system operation (Davies, 1984). The steady state operating mode of a power system is a balanced three-phase alternating current (AC) distribution system (Gupta, 2013). However, due to sudden external or internal changes in the system, the distribution operation is disrupted. On a 33KV distribution system, the common technical faults encountered often are:

1. Earth fault
2. Over current fault
3. Differential fault
4. Short circuit
5. Unbalanced 3 – phase effect.

These faults are mostly caused by natural and environmental factors such as:

1. Lightning
2. Heavy wind
3. Birds shorting lines
4. Trees shorting lines

However, the technical faults are caused by:

1. Excess load
2. Ageing of the conductors
3. Partial contact
4. Breaker failure
5. Ageing of substation equipments
6. Lack of maintenance
7. Physical vandalism.

These faults do not only have severe consequences on the socio-economic development of the nation but, can lead to loss of life and property as well as fire outbreak in the substation. At any voltage level, faults cannot be eradicated completely on a power system, they can only be reduced to the minimum by inculcating a good technical maintenance culture, employing well trained personnel and to ensure state-of-the-art maintenance and troubleshooting digital equipment (Adegboye, 1998).

MATERIALS AND METHODS

Electrical faults in power systems are divided into symmetrical and unsymmetrical faults.

Symmetrical Fault

A fault in a power system can be defined as a default in the electrical circuit due to which current is diverted from the intended path (Gupta, 2013). A symmetrical fault is a fault that involves all the three phases which occurs frequently in a power system (Gupta, 2013). The analysis of symmetrical faults includes the determination of the voltage at any point in the power system network, the current in any branch, and the value of the reactance necessary to limit the fault current to any desired value. Symmetrical components applied in the analysis of power system include:

- i. A positive sequence set of three symmetrical voltages i.e. all are equal and displaced from each other by 120°.
- ii. A negative sequence set of three symmetrical voltages having the phase opposite to the original set.
- iii. A zero sequence set of three symmetrical voltages, all equal in magnitude and in phase with each other. These symmetrical components are fundamental to power system analysis and can be used to transform and to compute the system response by direct circuit analysis on simple circuit models and transform the results back to the original phase variables.

Unsymmetrical Faults

Unsymmetrical fault is any fault that involves only one or two phases (Gupta, 2013). Majority of the faults in a power system network are unsymmetrical. Hence, the system requires protection against flow of heavy short-circuit currents (which may cause permanent damage to the major equipment) by isolation of the faulty area of the system by means of circuit breakers operated by protective relay.

Unsymmetrical faults are:

1. Single line-to – ground fault
2. Line – to – line fault
3. Double line – to ground fault etc.

The analysis of unsymmetrical fault conditions may be carried out using the method of symmetrical components by means of which an unbalanced 3-phase system of impedances may be resolved into three equivalent single-phase systems having independent impedance parameters (Akinsanya, 2005).

In general, there is evidently poor state of electricity supply at all voltage levels in Nigeria. At 33KV in Abeokuta Business Hub, the electricity supply nature is epileptic. Accordingly, this work investigates the fundamental problems in distribution network and proffers useful information and suggestions to ensure a good and rational planning and implementation policy by the electricity regulating body in the country. In particular, this research aims to identify common faults on 33KV distribution, to identify the causes of these faults, and to analyze the effect and suggest possible solution to attain good system stability.

Description of 33KV Distribution Network in Abeokuta

The 33KV distribution system in Abeokuta comprises of separate feeders or circuits radiating from a 132/33KV substation. Each feeder is designed to serve a particular area in Abeokuta and its environs. The 33KV network emanates from Gbokoniyi 132/33KV sub-transmission station, Ojere road, Abeokuta. This substation is fed with a bulk of power at 132KV from Ikeja West through Ota 132KV transmission lines. It receives the electrical power and steps it down to 33KV using a step-down power transformer. Gbokoniyi substation consists of 3 x 30MVA power transformers and radiates eight (8) 33kv feeders to different parts of the city.

Upgrade of 132/33KV Gbokoniyi Sub-station

In recent times, electricity demand increased tremendously due to both industrial and commercial development in Ogun State. This is also caused by the commercial business outstretch from the neighboring states, such as Lagos, Benin, Ondo, etc. Accordingly, Gbokoniyi sub-transmission station was upgraded to be able to meet with the demand. Presently, Gbokoniyi consist of a 2 x 60MVA, and 1 x 30MVA substation with eight (8) 33kv feeders radiating from the substation. The feeders are:

1. Imeko 33KV feeder
2. Lagos Road 33KV feeder
3. Water corporation 33KV
4. Abeokuta – Sagamu 33KV feeder
5. Owode lines 1&2 33KV feeders
6. Funnab 33KV feeder
7. Midgal 33KV feeder

These feeders radiate from Gbokoniyi sub-station. Most of the feeders are vulnerable to frequent fault as a result of excessive load current.

Figure 1 illustrates the block diagram of 33kv distribution system in Abeokuta and its environs.

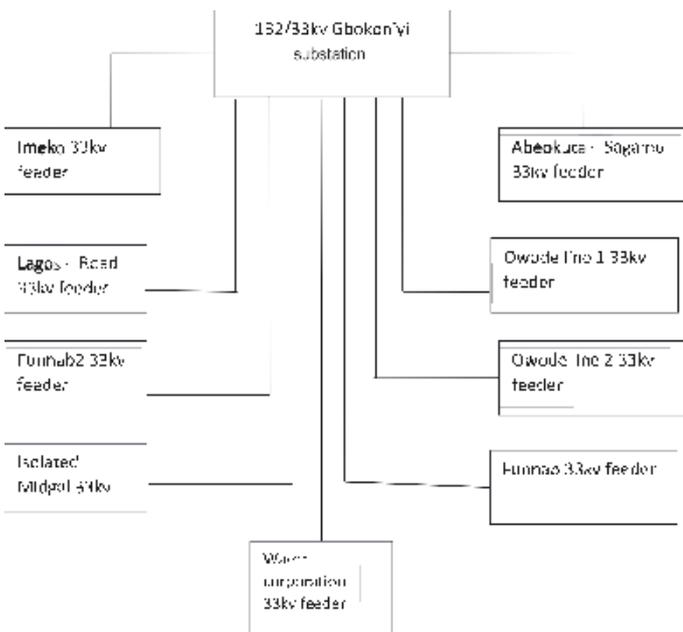


Fig.1: Block diagram of 33kv distribution system in Abeokuta

As part of the components of the distribution network, jumpers are used as switching devices to open and close a supply towards an area, most especially in times of emergency to a particular feeder from the adjacent one. There are circuit breakers to interrupt fault currents and isolators to physically open lines when required. Sulphur hexafluoride (SF6) circuit breakers are also installed for the newly installed power transformer in Gbokoniyi transmission sub-station, Abeokuta. The conductor sizes mostly used on a 33kv distribution lines are 150mm² Aluminum conductors along with other physical electrical gadgets to facilitate the ruggedness and durability of the physical structure of the 33kv distribution network in Abeokuta and its environs. These materials include: glass insulators, iron channels, pot insulators, hooks, high-tension poles (33ft) etc.

Newly constructed Abeokuta – Sagamu 132/33kv sub-station

A new 132/33kv sub-station

A new 132/33kv sub-station has been constructed along Abeokuta – Sagamu express road precisely opposite Paramount FM Radio station. This sub-station is designed to radiate six (6) outgoing 33kv feeders to boost power supply in Abeokuta and its neighbouring towns and industries.

The sub-station is designed with two (2) 60MVA power distribution transformers, current transformers, voltage transformers, isolators, SF6 circuit breakers, 132kv gantry, 33kv gentry, Aluminum steel reinforced conductors (250mm²), etc. It is designed to supply Funnab, Siun, Owode, and others so as to stabilize power in these areas and give a pressure and load relief to the existing Gbokoniyi sub-station. The schematic diagram of the newly constructed 132/33kv sub-station is illustrated in Figure 2.

It is pertinent to note that the sub-station receives its bulk power (132kv) from Ikeja West through Ota.

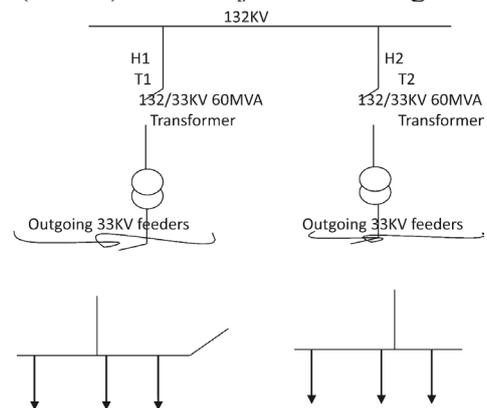


Fig. 2: One line schematic diagram of newly constructed 132/33kv sub-station along Abeokuta – Sagamu Express Road

Figure 2 shows that the sub-station is very flexible and reliable in such a way that either or both power transformers can be engaged to supply three (3) feeders or all the six (6) feeders at a point in time (Brown, 1988; Onohaebi, 2009). In the same vein, each circuit can be isolated to carry out maintenance and repair activities if required. Isolators (H) are equally installed on each outgoing feeder to control its circuit as desired by the technical personnel in the sub-station, and this enhances the flexibility of the system.

AC Distribution Feeders

Distribution system begins at the sub-station where power is delivered by overhead transmission lines and stepped down by transformers. Where a large area is involved, primary and secondary distributions may be used.

Distribution of alternating current (AC) power is usually available in the following system:

1. Single phase, 2 wire system
2. Single phase, 3 – wire system
3. Two phase, 3 – wire system
4. Two phase, 4 – wire system
5. Three phase, 3 – wire system
6. Three phase, 4 – wire system

The elements of distribution systems are: *feeders, distributors and service mains*.

Feeders are the conductors that connect the sub-station to the distributors servicing a particular area (Gupta, 2013). They may be in radial, parallel, ring or interconnected form.

(1) Radial Feeders: - In this system, the feeder radiates from the sub-station and branches into sub-feeders and laterals which extends into all parts of the area served. The transformers are connected to the tapping along the length of the feeders. Radial feeder is the simplest, most economical, and commonly used form of feeder. It is advantageous for supplying power to heavy industrial load near the sub-station.

(2) Parallel Feeders: - In this system, two radial feeders originating from the same or different sub-stations are run in parallel. Although each feeder can supply the entire load, they share the total load equally in normal conditions. This system is expensive but reliability is increased in the case of fault on one feeder, the total load can be supplied by the healthy feeder. Hence, interruption of supply is only for the time duration that is taken in transferring the load from the faulty feeder to the healthy one which is done either by manual or automatic switches. This system is employed whenever the continuity of supply is of great importance.

(3) Loop Feeders: – It is also called Ring main feeder. This system involves two or more radial feeders originating from the same or different sub-stations laid on different routes of load areas. The arrangement having the ends of two feeders tied together through normally open switching devices. This is known as open-loop system. The other arrangement has the ends of the two feeders tied together through normally closed switching devices, and this is called the Ring main feeder or Ring loop. This system is by far the most reliable for continuity of supply and gives better voltage regulation and less power losses.

(4) Interconnected Feeders: – When the feeder ring main is energized from two or more sub-stations, it is called interconnected Network System for interconnected feeders; power can be supplied to all the distribution transformers even though a part of the network may be out of service. This system provides better reliability and flexibility and it is employed in large metropolitan cities where constant power supply is very paramount (Allan and Roy, 2000).

The methods employed in this research work also involved inspection of various 33kv distribution physical structures, and the effects of the topography on some of the routes. This inspection was carried out to assess the physical condition of the system components from one point to the other. Also, assessment was done on sub-station equipments and installation of necessary gadgets to minimize faults on the system.

The available fault data obtained from the control room technical personnel was analyzed exclusively for present and future use. The data obtained was comprehensive enough to express the reliability, durability, and sustainability of the network taking cognizance of frequent occurrences of major faults in the network as a whole.

Abeokuta 33kv feeders and their peak loads

There are eight (8) 33kv feeders radiated from Gbokoniyi 132/33kv sub-station in Abeokuta. These are illustrated with their respective peak loads. The peak load is the maximum load a substation can take or withstand without stress or breakdown (Gupta, 2013). This can be expressed as:

$$P = IV \times \text{Cos } \phi,$$

(1)

where

I – Current (A); V – Voltage (V); Cos φ – Power factor.

Table 1. Abeokuta 33kv feeders and their peak loads.

S/N	Feeder	Peak Load (MW)
1	Lagos Road	14.5
2	Imeko	10.8
3	Funnab	15.2
4	Owode 2	18.2
5	Water Works	2.5
6		10.5
7	Owode Line	12.2
8		0.8
	Abeokuta/Sagamu	
	MIDGAL	

Analysis of different types of faults on the 33kv feeders.

There are various types of fault that hinder or affect the electricity supply at 33kv voltage level. The common faults on Abeokuta 33kv feeders are analyzed and illustrated in Table 2.

Table 2. Approximate percentage of various faults and their occurrence.

Fault	No of occurrence	Percentage of occurrence
Earth fault	9	12.2%
Short circuit	15	20.3%
Burnt cable	7	9.5%
Broken Pole	19	25.7%
Vandalisation	10	13.5%
Weather	3	10.8%
Miscellaneous (Accident, fire outbreak, tree falling etc)	6	8%
TOTAL	74	100%

$$\text{Percentage of occurrence} = \frac{\text{No of occurrence of a fault} \times 100}{\text{Total of occurrence of the faults considered}} \quad (2)$$

Frequency of Fault Occurrence in different 33kv feeders in Abeokuta.

Each 33kv feeder experiences different type of fault at a particular period of time or season of the year. The frequency of the faults on each feeder was recorded from the fault log book. The analysis is illustrated in Table 3.

Table 3. Frequency of fault occurrence in different Abeokuta 33kv feeders

Feeder (33kv)	No of fault occurrence	Percentage occurrence (%)
Lagos Road	26	39.3
Imeko	18	27.3
Old Owode	6	9.2
Funnab	11	16.6
Water Works	5	7.6

33/11KV Injection Sub-stations

Power distribution at 33kv voltage level radiates from Gbokoniyi 132/33kv sub-station (transmission station) to different parts of Abeokuta to supply different loads at different locations. This arrangement gives a segmented supply to different parts of the city with different reliabilities. The 33kv is further stepped down to 11kv at the injection sub-stations which are situated at the central position of the loads. The 33/11kv sub-stations radiate 11kv to various consumer sub-stations which comprise; industrial, commercial, and domestic consumers. The 33/11kv injection substations are listed in Table 4 with their respective transformer capacity:

Table 4. 33/11kv Injection Sub-stations in Abeokuta.

S/N	Sub-stations	Transformer Rating (MVA)	Load capacity at 0.8pf (MW)
1	Lagos Road	1 x 15 MVA	12
2	Olomore	1 x 15 MVA	12
3	Iberekodo	1 x 15 MVA	12
4	Rounda	1 x 15 MVA	12
5	Ayetoro	1 x 7.5MVA	6
6	Abiola Way	2 x 15 MVA	24
7	Old Owode Road	3 x 30MVA	36
8	Eleweran	1 x 15MVA	12

Fault Analysis on 11KV distribution feeders in Abeokuta.

Apart from water works 33kv feeder, and few industries that are fed at 33kv from Gbokoniyi (132/33kv) transmission station, other sub-stations are fed from injection sub-stations at 11kv to supply power to different areas in Abeokuta City.

The 11KV distribution network employs a radial connection. This involves separate feeders radiating out of the injection to serve a particular area. These 11KV feeders are equally vulnerable to different electrical faults which are illustrated in Tables 5 - Table 8.

Table 5. Old Owode 33/11KV Injection Sub-station

S/N	11KV Feeder	No of fault occurrence	Percentage % occurrence
1	Onikolobo	13	23.7
2	Akin Olugbade	13	23.7
3	Totoro	18	32.7
4	Ake	7	12.6
5	Ijaiye	4	7.3

Table 6. Eleweran 33/11KV Injection sub-station

S/N	11KV Feeders	Number of fault occurrence	Percentage % of occurrence
1	Ijeun Titun	11	22
2	Abiola Way	16	32
3	Obantoko	14	28
4	Odeda	9	18

Table 7. 33/11KV Lagos Road Injection sub-station

S/N	11KV Feeder	Number of fault occurrence	Percentage % of occurrence
1	Iberekodo	17	31.45
2	Mawuko	11	20.35
3	Ita-Oshin	26	48.20

Table 8. 33/11KV Rounder Injection sub-station

S/N	11KV Feeder	Number of fault occurrence	Percentage of occurrence
1	Brewery	13	26
2	Sabo	9	13
3	Soyoye	17	34
4	Ayetoro	11	22

Water Works 33/11KV Sub-station

This sub-station is a dedicated line which means that the feeder is strictly meant only for the water works operation. No other load is connected to the dedicated line. The 33KV radiates directly from Gbokoniyi transmission station to the Water Works substation where it is stepped down to 0.415KV for the operation of the heavy duty electric water motor pumps and other machine. Being a dedicated line, the fault occurrence is very minimal and negligible because the load demand is within the capacity of the sub-station transformers.

OVERALL FREQUENCY OF FAULT OCCURRENCE IN ABEOKUTA 33KV POWER DISTRIBUTION NETWORK IN 2018.

An analysis was done through the data collected from the central control room report log book to estimate the total number of fault occurrence in each month of the year 2018. Table 9 shows the summary of the data collected. The assessment is based strictly on occurrence of new fault on the 33KV feeders. According to the report in the log book, it took some time to restore some fault feeders due to logistics.

Table 9. Frequency of fault occurrence on 33KV Feeders in 2018

Month	Number of fault occurrence	Percentage of occurrence %
Jan.	11	10.67
Feb.	9	8.73
Mar.	6	5.82
April	13	12.61
May	12	11.64
June	10	9.70
July	9	8.73
Aug.	7	6.79
Sept.	8	7.76
Oct.	5	4.85
Nov.	6	5.82
Dec.	7	6.79

RESULTS AND DISCUSSION

Tables 1 -Table 8 above give different submissions on various analyses of the 33KV distribution feeders in Abeokuta.

From Table 2, it can be deduced that the poor condition of the High Tension (HT) poles accounts for highest number of times of fault occurrence in the network. The HT Poles are either falling or broken which causes the lines to twist together, hence, causing short circuit on the system and incessant power outage. The poles are the physical supporting structures of the distribution system with cross-arms and pot insulators. The distribution network is characterized by bending

poles, cracked pot insulators and dislocation of the cross-arms. Predominantly, short circuit is the most common and dangerous fault that occurs in a power system. It occurs as a result of twisted current carrying conductors or phases, breakdown of insulation. Hence, the short circuits and earth faults are common faults on 33KV distribution system in Abeokuta.

Feeders

The Lagos road 33KV feeder is found to be susceptible to more faults than all other feeder in Abeokuta 33KV feeder distribution system. This is established from Table 3, which shows that the Lagos road feeder has the highest percentage of fault occurrence. It was noticed that the topography of the route of this feeder affected the physical condition of the structure which causes frequent fault on the feeder. Some of the poles are bending while some are broken which makes the lines to twist when there is wind or storm during rainy season.

Injection Sub-stations

With the exception of Ayetoro 33/11KV injection sub-station that has 7.5MVA power transformer, all other 33/11KV injection sub-stations are eight in number namely: Lagos Road, Olomore, Iberekodo, Rounder, Ayetoro, Abiola Way, Old Owode Road and Eleweran 33/11KV injection sub. The assessment carried out on these injection sub-stations is highlighted below:

On old Owode 33/11KV injection sub-station, the Totoro 11KV feeder has the highest number of fault occurrence followed by Onikolobo and Akin Olugbade. Other feeders are Ake and Ijaiye with low number of faults occurrence.

The 33/11KV Eleweran injection sub-station feeds four (4) 11KV feeder within its reach. They are Ijeun, Totoro, Abiola Way, Obantoko and Odeda 11KV feeders. The Abiola way feeder is more vulnerable to fault with highest percentage of fault occurrence.

The rounda injection sub-station has four (4) 11KV feeder connected to it. They are brewery, Sabo, Ayetoro and Soyoye. Soyoye 11KV feeder has the highest percentage of fault occurrence. The assessment done on the fault occurrence on 33KV feeders shows that there are more fault occurrence in the month of April and May. The data was captured from the monthly report log book. The fault occurrence is less in October, November and December, respectively.

Based on the findings in the data collected, the physical condition of the overhead aluminum conductors, the 33/11KV sub-stations and other system components were assessed to establish the analytical feature of the faults in the distribution network.

CONCLUSION

It can be inferred from the results obtained that the frequent occurrence of short circuit and Earth fault on 33KV and 11KV feeders had been a major cause

of incessant power outage and electricity supply interruption in Abeokuta. It was also established in the cause of this work that the faults occur due to twisted HT lines or conductors as a result of leaning or broken poles.

Also, short circuit and earth faults occur in the cable due to overheating that breaks down the insulation between the phases, or phase and the ground. Other faults are caused by vegetation, weather and natural factors (Abiola and Adekilekun, 2013).

From this research work, it was found that the total load demand in Abeokuta is 80MW but 25-30MW is always allocated due to the ageing and weakness of the aluminum conductors on 132KV lines that fed 132KV/33KV Gbokoniyi sub-station. Hence, any increase above 30MW will cut off the 132 HT lines due to inability to carry the total load currents.

The study has shown the analysis of fault on 33KV factor distribution network in Abeokuta and

by extension, the fault occurrence on 11KV network which also reflected various fault on different feeders.

A recommendation is necessary to improve power distribution on 33KV system. In power system, the transmission lines are most susceptible to faults due to the environmental and topographical terrain on which the power transmission towers and steel supports are mounted. Over-aging of the conductors also makes the transmission lines vulnerable. Therefore, for Abeokuta to experience a stable power supply, the 132KV and 11KV poles should be replaced outrightly. In addition, all the broken HT 33KV and 11KV poles should be replaced and erected firmly and other defective physical structure components like, cross-arm, insulators, etc., should be replaced. Response time to fault clearing should also be improved upon and periodic line inspection and patrol must be conducted. Also, preventive maintenance on the sub-stations and line routes must be carried out.

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