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Electrical Fault Analysis of 33KV Distribution Network (A Case Study of Ekiti State 33KV Distribution Network)

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Abstract: - The aim of this research work is to carry out a fault analysis of 33KV distribution system using Ekiti state as a case study. Based on the available statistical data, Ekiti State is reported to suffer from severe shortages of electric power due to dilapidated and outdated electrical power infrastructures. In this research work, electric power infrastructure and energy availability in Ekiti State is studied since the state is one of the principal economic and political hubs of Nigeria. During the study, the conditions of all relevant electrical facilities for distributing power at the 33 KV level were assessed. Power availability in the 33/11kv injection stations in the state was considered by collecting data about energy supplied, faults and other outages. The outcome of the research indicated that the probability of having 2 consecutive hours of power was less than 25% in either year for most of the feeders indicating a very poor situation for consumers, especially small scale industries and commercial enterprises can only succeed using other sources of electricity. Faults on the feeders manifest a log-normal shape of the distribution which exhibited about 3000 earth faults over a nine year period corresponding to about $9x10^{-3}$ earth faults per MVAhr. Based on these findings, it can be deduced that not only is the physical equipment in need of serious rehabilitation and normalization, but also that even the power supplied requires better maintenance management to ensure delivery when available.

Keywords - Distribution, *Over-current, Feeder, Earth Fault, Load demand, Transformer*

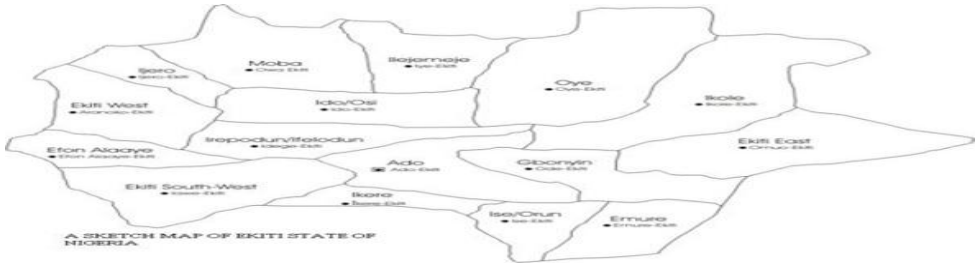
I INTRODUCTION

In recent years electric power has become the most ubiquitous form of energy used for production, recreation, control and for carrying out most activities because of the ease with which it can be produced, transported and converted to various applications. Gordon Clapp, a former General Manager of the Tennessee Valley Authority (U.S.A) once said- "If you would destroy a region, you destroy its power supply. If you would hold a region to a lower standard of living, you can do it by placing a limit on its supply of electric power" (Uwaifo, 1994). Given its benefits to mankind, it was not long before electricity was regarded as an infrastructure, i.e. a basic necessity for man's socioeconomic well-being. It is now universally accepted that the social and economic factors which define the level of prosperity, are highly correlated with the level of demand for electric power.Ekiti State is an agrarian state in the southwestern part of Nigeria. The State lacks most of the infrastructures which is common in most of the developing countries. Of these is the poor state of electric power distribution, electric Power distribution system in Ekiti State is something of a major concern. There are more outages than uninterrupted power supply in most parts of the state all the year round. It is a known fact that electricity plays a dominant role in the socioeconomic development of any community. In view of the foregoing, this project seeks to identify the problems militating against regular, good quality of electric power supply in Ekiti-State with a view to proffering solutions and suggestions where necessary. This is to improve the socioeconomic life of the Power Holding Company of Nigeria (PHCN)'s customers in the state. Given this unsatisfactory state of affairs and the lack of comprehensive studies to formally guide the development of electric power in the state, there is a dire need for an assessment of the Ekiti-state electric power distribution with a view to quantifying the availability of electric power and examining some of the physical factors that may contribute to the poor state of the electric power infrastructure so that remedial suggestions may be preferred for improved system performance. It is in the light of this situation that this research has been

conceived so as to provide useful information about the present condition from which rational and well-thought out improvements can be planned and implemented.

II MATERIALS AND METHODS

A BRIEF PROFILE OF EKITI STATE



Map of Ekiti-State

2.1 Historical Background of Ekiti State

Ekiti State of Nigeria was created on 1st October, 1996 by the late Head of State and Commander-in-Chief of the Armed Forces of the Federal Republic of Nigeria, General Sani Abacha(GCON) .The State capital is located in Ado Ekiti.

2.2 The Ado- Ekiti District of the PHCN

The electric power distribution network of Ekiti State is under the management of the Power Holding Company of Nigeria (PHCN), Benin Distribution Zone and is referred to as Ado–Ekiti Business Unit. Ekiti-State which has no power generating capability is supplied from four different sources with capacities as shown in the table1.0.

Table 1.0: Ekiti-State 33kV Sources

S/N	Source	Transformer Capacity	Load Demand (MW)
1	Akure	2x30MVA	15
2	Omu Aran	2x1.5MVA	12
3	Okene	2x30MVA	3
4	Ilesa	2x30MVA	4

An estimated load demand of 34 MW can be satisfied from the sources as shown in table 1.0. Power distribution in Ekiti-State radiates outwards from a backbone and the distribution lines pass through thick vegetation/difficult terrain. This arrangement results in a fragmented supply to different areas of the state with different reliabilities, thus making maintenance and fault tracing on the network very tedious. Persistent low voltage due to the poor supply conditions has forced artisans and big electricity consumers depend on generators for their products and services. Ekiti State is serviced by 10 major injection substations and over 300 distributions. The main injection substations are highlighted in table 2.

Table 2: Injection Substations in Ekiti-State

S/N	Substation	Type KV)	Transformer Rating (MVA)	Source
1	Ijero	33/11	2.5	Ilesha
2	Oye	33/11	1	Omu-Aran
3	Ikole 1	33/11	2.5	Omu-Aran
4	Ikole 2	33/11	2.5	Omu-Aran
5	Ado	33/11	15, 7.5	Akure
6	Ise	33/11	2.5	Akure
7	Ikere 1	33/11	2.5	Akure
8	Ikere 2	33/11	2.5	Akure
9	UNAD	33/11	2.5	Akure
10	FED POLY	33/11	2.5	Akure

2.3 General Description of 33 kV Distribution Networks in Ekiti State

The 33 KV and 11 KV distribution networks in Ekiti-State are radial. The radial type system is the simplest and the one most commonly used. It comprises separate feeders or circuits radiating out of the substation or source, each feeder usually serving a given area (Pansini, 1986). The 33 KV network covers a

substantial part of Ekiti-State, this being fed from the four (4) sources of electric power. Ado, Ise-Orun, Emure, part of Gbonyin, Ikere, Irepodun/Ifelodun, Ekiti West and Ekiti South West Local Government areas receive supply via Akure-Ado 33kV line. The supply from Omu-Aran transmitting station covers Moba, Ikole, Ilejemeje, Ido/Osi and Oye Local Government areas. 33kV line tee-off from Kabba/Isanlu feeder from Okene transmitting station supplies power to Ekiti East Local Government Area while the Ikare feeder supplies power to part of the Gbonyin Local Government Area. Ado-Ekiti feeder, radiating from Ilesha transmitting station covers areas like Aramoko, Osi, Awo, Iropora, Eyio, Epe, Ado-Ekiti and environs. Ikogosi /Erijiyan 33kV line Tee-off from Efon Feeder supplies Ipole-Iloro, Ikogosi and Erijiyan-Ekiti.

There are two consumers that are fed at 33 KV. These are the Ero dam with 2 X 1.6 MVA operating 33/11 KV and the Ayetoro water booster station with 2 X 1.6 MVA also operates 33/11 KV. There are Ring Main Units (RMUs) at Ikere main substation No 1, Ikere main substation No 2 and Ikole main substation. These RMUs provide an arrangement for switching at the injection substations. There are also J and P/ 'D' fuses strategically located on the networks in order to provide protection against overload or over-current faults on the distribution transformers. The distribution transformers range from 50 KVA to 500 KVA ratings. Similarly, there are circuit breakers to interrupt fault currents and Isolators to physically open lines when necessary. There are also some arrangements for switching (jumper points) which can be closed in order to provide emergency supply to a feeder from an adjacent one. In the Ado main substation / control room, SF6 gas circuit breakers are installed for both of the 7.5 MVA and the 15 MVA transformers. The conductor sizes of the overhead lines are either 70mm2 or 100mm2. However, the Ido – Aaye – Ifaki – Oye route which is almost 32 km in length uses 150mm2 Aluminum conductor size while Ilupeju – Ire route which is 15km in length uses 35mm2 Aluminum conductor size.

III RESEARCH METHODOLOGY

3.1 Study Process for Assessment

The process of study of the assessment started with the evaluation of the physical condition of the distribution system with specific reference to the type and size of conductors, pole supports, spans and clearances, cross-arms, type of insulators and route length. A study of the operational and failure features of the network in terms of availability and quality of power, types of fault and frequency of occurrence of faults then followed.

Direct patrol and inspection of the 33 KV distribution network of Ekiti-State, as well as personal visits to injection substations for on–the-spot assessment of the state of equipment and installations of the injection substations were carried out. Fault data obtained from the Power Holding Company of Nigeria (PHCN), Ekiti State district for three consecutive years (2011- 2013) were collected and analyzed. Daily, hourly feeder loadings of the 11 KV distribution network in the district for two consecutive years (2009 – 2010) were obtained and analyzed. Also additional information was also obtained from interviews conducted with PHCN's staff and management and staff of Ekiti-State Electricity Board.

Table 3: 33kV Akure-Ado-Ekiti Route

ITEM	DESCRIPTON	QUANTITY	CONDITION	REMARKS
33kV line			Exposure to forest encroachment	Route not cleared.
Sag			About 80% of the spans met standard requirement	Improper construction and damaged cross arms and insulators are likely causes.
Distance		65 km in length	Only about 18 km of the route length is cleared.	Poor maintenance of the right-of-way by the PHCN due to inadequate funding and staffing.
Conductor	Aluminum	100 mm^2 in diameter	Loose strands are present	This is due to expansion of conductors as a result of overheating resulting from overload.
Sampled Poles	Tubular steel poles	489	134* (27%) poles were defective.	*The condition of the poles is due to either traffic accident or other factors like poor erection. Some of the concrete bases require re-construction.
Insulators	Post and pin type	1467	146 (10%) insulators were defective.	Insulators were affected due to rotten and broken cross arms. Some are also cracked due to old age, flashover and weather conditions.
Cross arms	Wooden	489	161 (33%) cross arms were defective.	Wooden cross arms are rotten, broken as a result of old age over-exposure to rainfall and sunlight.

Table 4: 33kV Ado-Ikere-Emure Route

ITEM	DESCRIPTION	QUANTITY	CONDITION	REMARKS
Line	33 kV		Line is exposed to forest encroachment.	The route is not cleared.
Sag			About 55% of the spans met standard requirement	The causes are likely the effects of damaged cross-arms, insulators and improper construction.
Distance		53.2 km in length	Only about 24 km (45%) is cleared	Negligence of the right-of-way by the PHCN due to inadequate funding and staffing.
Conductor	Aluminum	100 mm^2 in diameter	Loose strands are present	The loose strands are consequences of overload on the line conductors which cause them to expand.
Sampled Poles	Concrete	315	135 (43%) poles were defective.	The defects are due to poor erection and vandalism by trees during rainfall.
Insulators	Pin type	945	66 (7%) insulators were defective.	Displaced and broken insulators were due to rotten and broken cross-arms.
Cross arms	Wooden and steel	315	113 (33%) cross arms were defective.	Wooden cross arms are rotten, broken as a result of old age over-exposure to rainfall and sunlight.

Table 5: 33kV Ado-Aramoko Route

ITEM	DESCRIPTION	QUANTITY	CONDITION	REMARKS
Line	33 kV		Exposure to forest encroachment	The route was not cleared.
Sag			About 60% of the spans met standard requirement	Effects of damaged insulators and cross-arms.
Distance		32 km in length	Only about 26 km was not cleared.	Negligence of right-of-way by the PHCN due to inadequate funding and staffing.
Conductor	Aluminum	100 mm2 in diameter	Loose strands are present	This is due to expansion of conductors as a result of overheating resulting from overload.
Sampled Poles	Concrete	150	57 (38%) poles were defective.	The pole defects are due to the lack of concrete base of the poles and poor maintenance of route.
Insulators	Pin type	450	36 (8%) insulators were defective.	Some insulators were broken while some displaced due to rotten and broken cross-arms
Cross arms	Wooden	489	161 (33%) cross arms were defective.	The wooden cross-arms were rotten and broken as a result of old age and over-exposure to rainfall and sunlight.

Table 5: 11kV Ado-Iyin-Igede Route

ITEM	DESCRIPTION	QUANTITY	CONDITION	REMARKS
Line	11 kV		Line is exposed to forest encroachment	The route was not cleared.
Sag			About 60% of the spans met standard requirement	Poor construction and damaged cross-arms and insulators are likely causes.
Route		17.2 km in length	About 7 km (41%) was not cleared.	Negligence of the right-of-way by the PHCN inadequate funding and staffing.
Conductor	Aluminium	100 mm2 in diameter	Loose strands are present	This is due to expansion of conductors as a result of overheating resulting from overload.
Sampled Poles	Concrete and wooden	105	48 (46%) poles were defective.	Some poles were attacked by termite while some were not properly erected.
Insulators	Pin type	315	37 (12%) insulators were defective.	Some insulators were displaced due to rotten and broken cross-arms while some were broken due to weather condition.
Cross arms	Wooden and steel	105	45 (43%) cross-arms were defective.	The wooden cross-arms were rotten and broken as a result of old age and over-exposure to rainfall and sunlight.

Table 6: 33kV Ado-Ilawe Route

ITEM	DESCRIPTION	QUANTITY	CONDITION	REMARKS
Line	33 kV		Line is exposed to forest disturbance	The route was not cleared.
Sag			About 60% of the spans metstandard requirement	Effects of damaged insulators and cross-arms.
Distance		17 km in length	About 7 km (41%) was not cleared.	Poor maintenance of the right-of-way by PHCN due to inadequate funding and staffing.
Conductor	Aluminium	100 mm2 in diameter	Loose strands are present	This is due to expansion of conductors as a result of overheating resulting from overload.
Sampled Poles	Concrete	125	50 (40%) poles were defective.	The defects are due to destruction by trees during rainfall and poor erection of poles.
Insulators	Pin type	375	23 (6%) insulators were defective.	Some insulators were broken while some were displaced due to rotten and broken cross-arms.
Cross arms	Wooden and steel	125	41 (33%) cross-arms were defective.	The wooden cross-arms were rotten and broken as a result of old age and over-exposure to rainfall and sunlight.

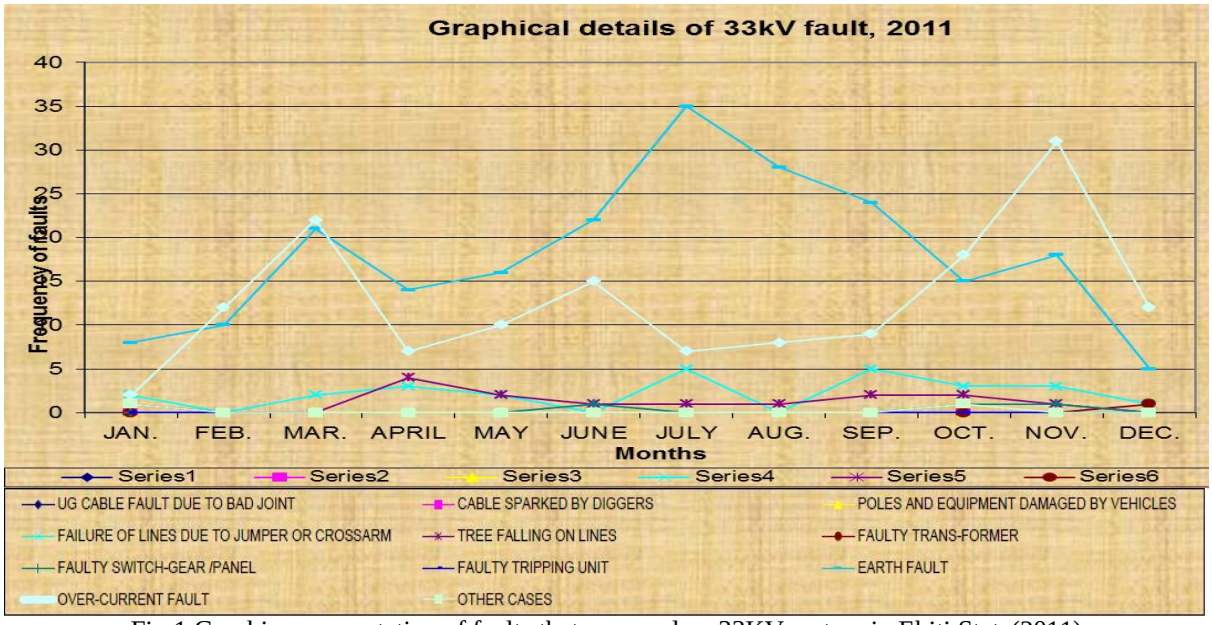


Fig 1:Graphic representation of faults that occurred on 33KV system in Ekiti State(2011)

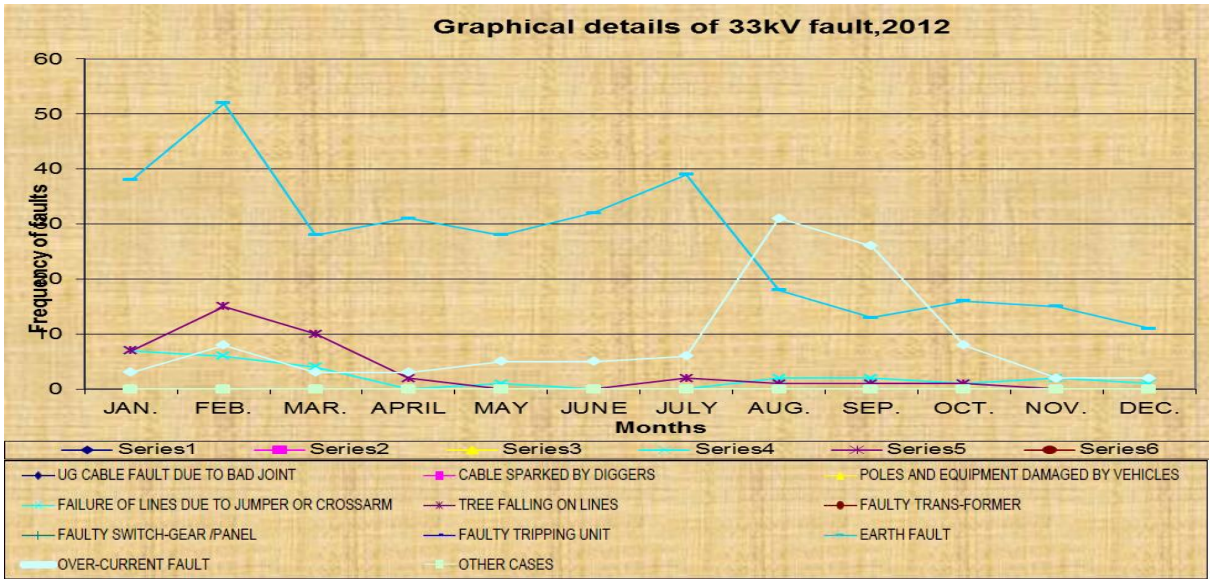


Fig 2:Graphic representation of faults that occurred on 33KV system in Ekiti State(2012)

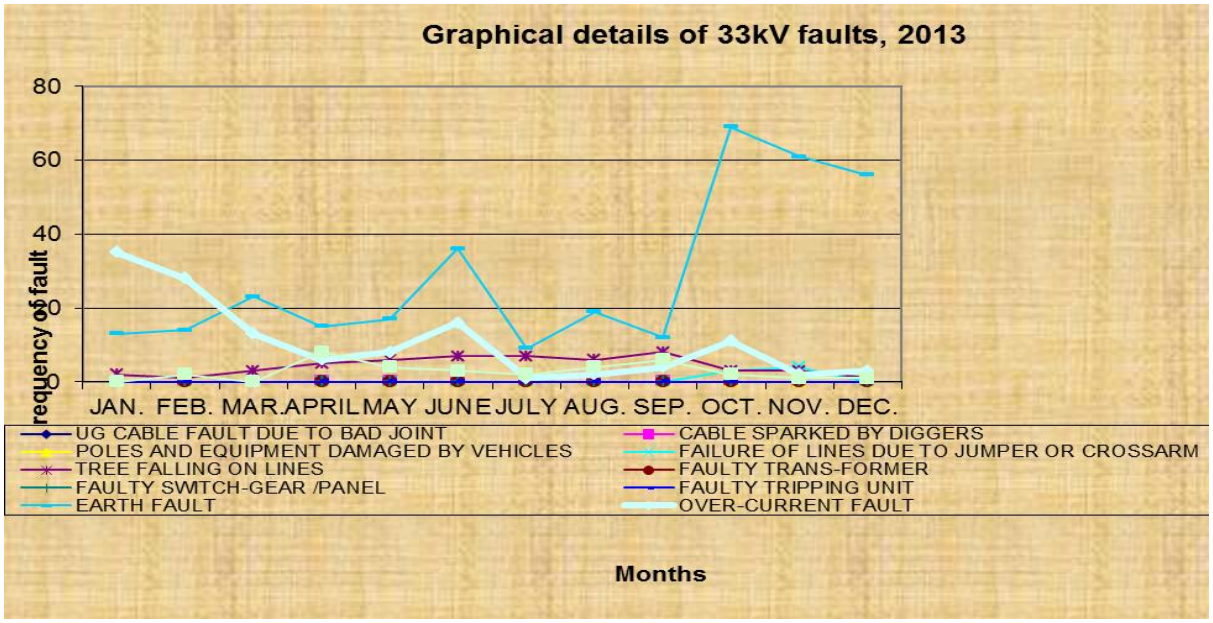


Fig 3:Graphic representation of faults that occurred on 33KV system in Ekiti State(2013)

IV RESULTS AND DISCUSSION

The following tables provide a graphic representation of the physical state of the components of the 33kV network in Ekiti State. The poor state of the lines accounts for the incessant outages and faults observed as shown in fig 1-fig 3 and Table 1-Table6.Inspection of the overhead lines revealed that in Ekiti-State, the supporting structures of the distribution systems are predominantly either reinforced concrete or wooden poles with a few steel towers, similarly with either wooden or steel cross-arms. The abundance of trees in Ekiti-State's forest makes the use of wood as supporting structures very economical. Most of the 'right-of-ways' in Ekiti-State pass through the forest due to the nature and topography of the state. However, the distribution networks were characterized by leaning poles or crooked structures, shattered insulators, broken or decayed cross-arms and vegetation encroachment. The data collected was compiled into a spreadsheet resident database from which many scenarios and analyses were deduced. Based on the findings in the data collected, the physical condition of the overhead lines, the substations as well as other relevant system components were assessed so that remedial measures could be determined. Power availability, loading characteristics of the district and probabilistic characterization of faults in the state were also carried out. Faults experienced on the 33kV distribution network of Ekiti State district between 2011 and 2013 were obtained from the Power Holding Company of Nigeria PLC (PHCN); the database contains details of types of fault cleared on a monthly basis for the period 2011 and 2013 on the 33kV network.

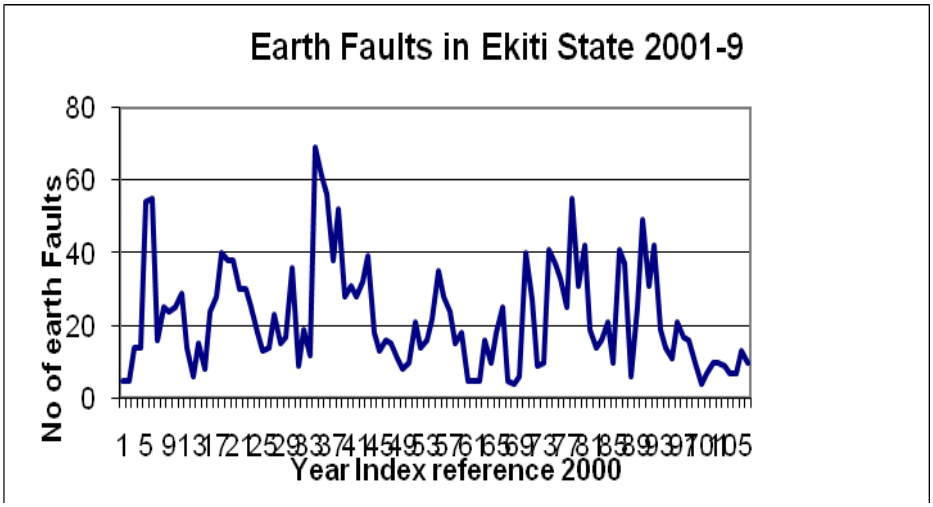


Fig 4: Earth Faults on 33kV network between 2001 and 2009

The fig 4 gives a plot of the frequency of earth faults observed on the 33kV network with year index reference 2000.

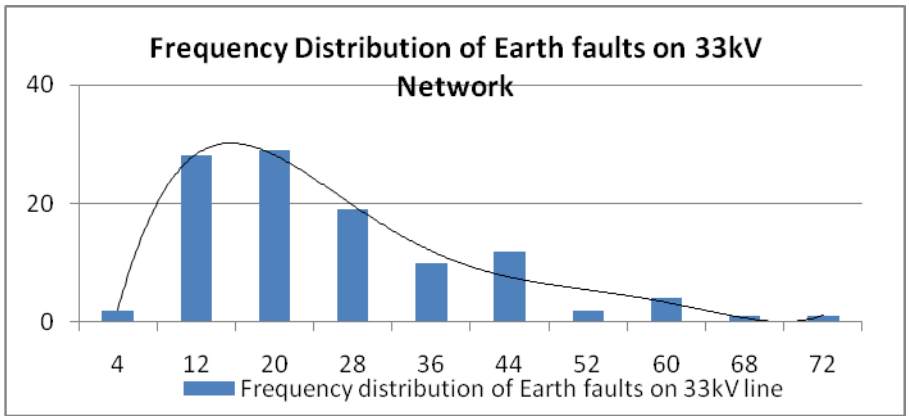


Figure 5: Frequency Distribution of Earth Faults on 33kV Network

The frequency distribution for the earth faults observed on the 33kV network is shown in fig 5.

V CONCLUSION AND RECOMMENDATIONS

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