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The Impact of Unplanned Outages on Power Lines Due To Vegetation Encroachment

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Abstract: *This study assessed the impact of unplanned outage on power lines due to tree/ vegetation encroachment whichis a common situation that power utility companies go through. UTC 33KV Feeder managed by Port Harcourt Electricity Distribution Company (PHEDC)is a tree / vegetation prone feeder. Comprehensive readings of forced outage due to vegetation on UTC 33KV Feeder for the year 2018 were collected as data for the study. The key performance indices of the feeder were generated using frequency and duration method. The analysis of these indices was done using Matrix Laboratory (MATLAB) software. Results revealed that forced outage resulting from tree/vegetation on UTC 33KV distribution line of 449hours 17 min stood at 5.13% of the forced / unplanned outage duration for the year. Hence using the reliability evaluation Indices, System Average Interruption Frequency Index (SAIFI) was high. The System Average Interruption Duration (SAIDI) was discovered to be poor. Customer Average Interruption Duration Indices (CAIDI) was also discovered not to be impressive. The Average Service Availability index (ASAI) came out to be average. The Reliability indices of the UTC 33KV feeder of SAIFI, SAIDI, CAIDI, ASAI all showed that the tree / vegetation encroachment on the power line brought about a major dislikeand negativeimpact to equally the utility providers and their customers.*

Keywords: *Impact, Unplanned Outages, Powerlines, Tree/Vegetation, Reliability indices, customers*

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I. INTRODUCTION

Power outages are undesirable. That is why such condition should be improved as best as practicable. Power outages happens due to a lot of reasons like transformer tripping on fault, line circuit breaker operating to open position on the relays seeing a fault in the power network. Also, tree / vegetation falling on power lines. In reality, vegetation has a significant place in human existence, it still could bring lot of discomfort if not managed properly. These could pose an extensive concern to human safety.These forced / unplanned outages caused by over grown tree encroachment in to power lines come in three forms:

*Tree branch growing into the energized line and bridging two phases;
*Tree failing structurally and striking power line structures during extreme weather;
*Tree branches entering in to the flash zone around an energized power line during sag and swing of the conductor lines.

Vegetation and trees constitute a central importance of our urban and country side environment. They cover a large area ofaesthetic, add environment value and benefits on both personal and public land. However, there are variety of concern regarding trees in same route and direction with power lines. Without the aid of electricity, numerous activities are likely to be impossible.

Electric service providers in their effort to make available safe and dependable services can meet with tree and vegetation obstacles. Mention must be made that safety around utility power lines is concern to everyone. Weather occurrence like wind and rainfall can cause power lines and other utility structures to be impacted by nearby trees and vegetation. As far as humans, trees and energized power lines coexist, vegetation / tree clearance program could be said to be absolutely necessary.The UTC 33KV Feeder managed by Port Harcourt Electricity Distribution Company (PHEDC) has a history of frequent trips / forced outages due to vegetation and over grown trees in and around a substantial length of the feeder. Due to the UTC 33KVfeeder frequent outage, there is clear evidence that the customer service availability is not what is supposed to be.

Aibangbee and Chukwemeka (2017) planned and forced events interferes with normal operation condition that can lead to electricity supply loss and interruptions. The forced events are caused by a number of times due to human error or from equipment failure. Trees / vegetation can also bring about loss of supply to power lines that are around theircorridor.The consequence of a tree-caused incident is of extreme interest. The approach being proposed considers three categories of resources: Those specifically related to restoration and repair, other indirect cost to the utility and the societal inconveniences of power line outages.Safety and reliability are a serious concern to both power utility companies and power customers. Hence implementation of strategies to reduce feeder forced outages resulting from trees and vegetation encroachment was investigated.

The scope of this work covered the influence of forced outages of UTC 33KV feeder due to vegetation/ tree encroachment for the physical year 2018. The study of the dependent indices of the feeder using Frequency and duration of data were obtained, comprehensive data from the daily report on the UTC 33KV feeder, the forced / unplanned outages, resulting from tree / vegetation encroachment on the feeder, the potential for total outage period of the power lines due to vegetation and over grown trees were also analyzed.

Reliability and key Performance indices of the feeder was analyzed to show that frequent outage on the feeder reduces the reliability of the feeder. Percentage of the cumulative forced outage due to tree / vegetation encroachment was analyzed. This work brought out areas which the PHEDC should develop, to increase potential of the UTC 33 KV feeder. This will result to betterand quality electricity supply to the users tied to the feeder. Customer on the UTC33KV feeder will be better off in attending to their numerous daily engagements if these unplanned outage frequency and duration of outage are improved upon.

II. LITERATURE ASSESSMENT

In engineering, reliability could be said to be possession of a system or component to perform its required function within stated perimeters for a specified duration of time. Fellow (2016) in his bow-tie analysis bring about the possibility to describe mathematically an overall extent of risk exposure for a specified incident. His work included development of algorithms intended to break down the connection between an overhead power system's exposure to tree-related probability and the severance of exposure.The analytical model being proposed looked at the evidence of data and the main expected outcomes before considering a reasonable range of variables which were selected base on two attributes. Variables include those that explain specifically the system being maintained; the incident of interest; hazards that open up the system to an unwanted occurrence, including their probabilities; risk-mitigation methods, resources and their efficacy; and the resulting effect of the occurrence, both looking at damage done and costs.

The consequence of a tree-caused incident is of extreme interest. The approach being proposed considers three categories of resources: Those specifically related to restoration and repair, other indirect cost to the utility and the societal inconveniences of outages. The pain of an outage to customers can be very severe than the utilities' direct cost. Classifications breaks it in to the possibility to consider consequences external to the utility.The proposed analytical model is conceptual in character, it has no record of been tested under operational conditions. The logical foregoing step is validation. First step being considered involves using existing industry data sets is to grow a logical straw man representing a typical Utility Vegetation Management (UVM) program. The straw man is planned as a hypothetical yet relatively accurate representative surrogate for the industry. The resulting hybrid virtual UVM program would be applied in initial validation testing. Final validation would be achieved by conducting in a pilot project hosted by a willing utility.

Forced outages result from contingencies. Aibangbee and Chukwemeka (2017) Planned and forced events interferes with normal operation condition and can lead to electricity supply loss and interruptions. The forced events are caused a number of times due to human error or from equipment failure. Trees / vegetation can also bring about loss of supply to power lines that are around theircorridor.Trees, shrubs and vegetation are of needed importance to our environment and our daily life. They provide cover around our walk ways and houses, offer a safe place forbirds, wildlife, and filter / absorb a lot of air pollutants. However, vegetation in proximity to power lines may be an access to serious risk to people safety, their properties and environment. These closeness between trees and supply lines is one of main source of power interruptions. It is in the public domain that trees structural failures which make them to drop across supply lines are the highest cause of outages, causing significant power outages sometimes bushfires. It is not unimaginable that vegetation handling procedures in utility corridors bring about an exceptional maintenance cost to electrical utility companies. In reality, activities relating to tree trimming in combination with vegetation clearing are costly. Power companies, spend reasonable sum of resources a year critically looking at vegetation encroachments and taking care as they impact power lines. Appropriate and result oriented vegetation clearance not only bring down the overall expenditure but also lead in continuous power supply by shielding negative impact on power lines by removal of fast-growing natural species. Nonproductive procedures can bring about loss of reliability in power transmission, produce severe hazards there by exposing utility companies to major financial loss.

Tree trimming clearances used by any utility company has to be in line with the state wide standard for vegetation pruning and to create safe distances from supply lines. Tree trimming measurements requirements should be visited periodically. The Vegetation Clearances around Urban and Rural Power lines has a standard clearance distances requirement.In some rural situations where power line spans are longer than 100m, greater clearance distances are needed in the mid part of the span to take of the sag and swing of power lines in hot and windy conditions.Clearances between trees and bare conductor lines increase as voltage and span distance of the conductor lines increase. Clearances in the mid part of span are greater to give way for conductor swing and sag for any spans greater than 100m.Some properties could be guided by easement conditions that impose even greater clearance distances. A tree's nearness to electricity caring lines and the trimming required to effect clearance distances may mean some trees are removed completely.

Safety around supply utilities is a concern for everyone. Most tree disagreement are as a result of tall-growing nature of the trees planted very near to or exactly under conductor wires, hence resulting to branches then growing into legally clearance limits .A lot of issues arise from natural weather events, like wind and severe rain fall that come with storms bringing about limbs or sometimes whole trees falling into power lines and structures owned by the utility companies.George (2014) opined service cables in hard contact with stiff tree structures, such as branches or trunks, may have the insulation covering worn away, and a short circuit or grounding can occur, which can result in flickering lights and/or blowing of the transformer rated protective fuse.

The system capability could also be evaluated in the whole distribution system containing system reliability indices. These indices represent the adequacy in the entire system supply then show the system ways and response.System Average Interruption Frequency Index (SAIFI). The index depicts the average figure of sustained unplanned outages experienced by the customer with in a period (generally 1 year). The exact meaning referring to service area can be easily change looking at the numberof all customers and power interruptions they experienced changes in reference to the way the enclosed area is defined. Looking at a case, a feeder SAIFI shows the average figures of power outages a customer serviced via a particular feeder has experienced within a year. Identically SAIFI reported generated through a substation or power distribution system encloses the whole customers in the area served. SAIDI (System Average Interruption Duration Index): the average period for which power supply to customers is interrupted in physical year. CAIDI (Customer Average Interruption Duration Index): the average period needed to restore quality service per sustained interruption to the average supplied customer. The average service availability index (ASAI) gives a fraction of reporting time that the customer power was available. Higher ASAI values mirrors higher rating of reliability.

Ahmed (2016) opined that the main feature of quality is continuing of supply when it comes to electric power network operation, technical quality and safety of the commodity, service to end users and impact to the environment. Being able to measures the Continuity of supply to the customer shows the ability of the electric network providers. It is unanimously characterized to be the frequency together with the duration of interruptions in power supply. The distribution delivery arrangement has a great influence on reliability.Adegboye (2010) reportedthatpoweroutages on the feeders were traced to the damages done to the overhead lines due to heavy winds, thunder strikes, storm and other disturbances associated with rain. For power lines with Tree/ vegetation along its corridor, there is high possibility of vegetation and tree falling on power lines during this type of condition. The system capability could also be evaluated in the whole distribution system containing system reliability indices. These indices represent the adequacy in the entire system supply then show the system ways and response.

In this work, the impact of tree/ vegetation when they bring about unplanned power outages was investigated. The feeder has sixty-six (66) fully grown trees along its route / corridor and nine fully grown palm trees also along its route. Transient fault on the power line resulting from these tree and vegetation was also observed in the data collected. This transient type of fault resulted from the UTC 33 KV feeder sagging due to load of more than 80% of its load carrying capacity which is 15mega watt (MW). At this point, if wind makes the line swing closer to the nearby tree branch in to the energized zone / flash zone, it is picked up as an interference, hence the protective relay sees it as a fault and then trip, thereby putting the line out on forced outage. On patrol by the work crew, they observe no physical or direct contact made between the tree/ vegetation and the overhead line. The frequency and duration of the forced outage due to transient, tree/vegetation was extracted from the data collected for the whole unplanned/forced outages on UTC 33KV feeder and analyzed. Cost of interruption and frequent and extended lack of electricity can have severe economic impact on the service providers and its customers.Okereafor (2017) observed that the consequence by which a country is under developing is the issues of incessant power interruption, inadequacy, unreliability and unclean power supply.

III. MATERIALS AND METHODS

Description of UTC33kv feeder

The feeder could be classified as a radial line. Akintola (as cited in Anthony, 2014). A radial system fundamentally consists of specified series components like breakers of various types, lines switches, chosen transformers and then end-users "Customers". It takes off from Port Harcourt town 1x60MVA, 1X45MVA,2X30MVA 132/33KV Transmission Station (T/S). It ends at an injection sub-station called Reclamation 15MVA 33/11KV injection substation. The feeder dropped in to UTC 15MVA 33/11KV injection substation. 3Km is the route length of the supply feeder. With 1.2km of it made up of 150mm Aluminum Core Steel Reinforced (ACSR) type conductor. Then the remaining length of 1.8 km is made up of 150mm All Aluminum Conductor. (AAC) The maximum load the line can carry is 15MW. See Fig 1. The feeder has sixty-six fully grown trees along its route / corridor and nine fully grown palm trees also along its route.

Materials consideration

Materials were sourced from various books, publications, thesis, daily readings(data), general unplanned/forced outages and forced outage data resulting from vegetation encroachment on the UTC 33KV feeder for the year 2018. Distribution transformer ratings, the total number of customers tied to the feeder, vegetation clearance schedule for the year 2018.Data were obtained from daily information report log of Port Harcourt Electricity Distribution Company (PHEDC) and Transmission Company of Nigeria (TCN), Port Harcourt Town Transmission Station (T/S).

Method applied

Descriptive study methodwas applied by collecting data of general unplanned power outage. The data for the unplanned outages due to tree/ vegetation was then extracted as the dataof interest of this study. This Data was thencomputed using frequency and duration customer orientation reliability indices and analyzed using MATLAB software to show the impact of tree/ vegetation on UTC33KV powerline/ feeder customers.

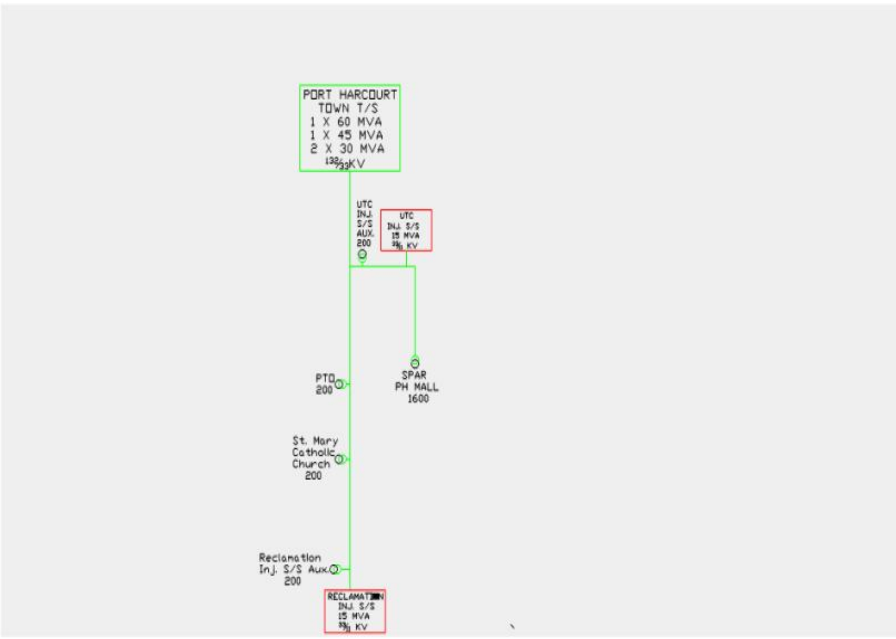


FIG 1: UTC 33KV Feeder Single Line Diagram

From the data collected, forced outages and their frequency was deduced, then also the duration of each unplanned outagewas also calculated. Using the difference between the outage time and the time the feeder was restored back to service.Reliability indices which gives system average interruption frequency index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI) and Customer Average Interruption Duration Index (ASAI), were calculated and analyzed using Matrix laboratory (MATLAB)software.

The first calculation of general forced outage was for aduration of 4240 hours when the feeder was out and then for449:17 hours of this duration, it was out on tree/ vegetation outage which is 5.13% of forced outage duration for the year 2018. This work was able to go specific on the tree/ vegetation related unplanned power outages.

The primary load spot indices introduced earlier are very significant looking at customer standpoint. The system capability could also be evaluated in the whole distribution system containing system reliability indices. These indices represent the adequacy in the entire system supply then show the system ways and response.

System Average Interruption Frequency Index (SAIFI). The index depicts the average figure of sustained unplanned outages experienced by the customer with in a period (generally 1 year). The exact meaning referring to service area can be easily change looking at the that numberof all customers and power interruptions they experienced changes in reference to the way the enclosed area is defined. Looking at a case, a feeder SAIFI shows the average figures of power outages a customer serviced via a particular feeder has experienced within a year. Identically SAIFI reported generated through a substation or power distribution system encloses the whole customers in the area served. SAIDI (System Average Interruption Duration Index): the average period for which power supply to customers is interrupted in physical year. CAIDI (Customer Average Interruption Duration Index): the average period needed to restore quality service per sustained interruption to the average supplied customer.

The system average interruption frequency index

$$SAIFI = \frac{\sum Total\ number\ of\ Customer\ Interruptions}{Total\ Number\ of\ Customers\ served} \quad (1)$$

$$SAIFI = \frac{\sum N_i}{NT} \quad (2)$$

System Average Interruption Duration Index(SAIDI)

$$SAIDI = \frac{\sum Customer\ Interruption\ Durations}{Total\ Number\ of\ Customers\ Served} \quad (3)$$

$$SAIDI = \frac{\sum r_i N_i}{NT} \quad (4)$$

Customer Average Interruption Duration Indices (CAIDI)

$$CAIDI = \frac{\sum Customer\ Interruption\ Durations}{Total\ Number\ of\ Customer\ Interruptions} \quad (5)$$

$$CAIDI = \frac{\sum r_i N_i}{\sum N_i} = \frac{SAIDI}{SAIFI} \quad (6)$$

Average Service Availability Index (ASAI)

$$ASAI = \frac{Customer\ hours\ Service\ availability}{Customer\ hours\ services\ demand} = \frac{NT \times 8760 - \sum r_i r N_i}{NT \times 8760} \quad (7)$$

Where

N_i is the number of customers interrupted for every single interruption event within the reporting duration.
NT represent the total value of customers in the said area served.
$r_i$represents reinstating time for every interruption event.

IV. RESULTS AND DISCUSSION

Unplanned UTC33KV powerline outages due to tree /vegetation was considered for this work,in the period of

physical year 2018 January to December. For 4240 hours duration the feeder was out on general forced outage and 449:17 hours of this duration, it was out on tree/ vegetation outage which is 5.13% of forced outage duration for the year. Ahmed (2016) found that main aspect of quality for electric network operation are continuity of supply, safety, technical quality of the commodity, end user service and environmental impact.These unplanned outages are Presented in table 1.

In January, there was no record of any vegetation related forced outage.By February, three faults were recorded, there was vegetation encroachment and palm tree branch taking away from the line. The feeder also went out on transient fault as nothing was observed after patrolling the line The line was out on tree / vegetation fault for the period of 32:47 hours. This represent 13.53% of the total 240hours the line was out on forced outage for the month.

In the month of March, tree/ vegetation was taken off from the power line and also on another forced outage nothing was observed on the line after patrol crew went through the stretch of the feeder indicating this resulted from a transient fault. Total outages frequency experienced in the month was two. Hours the feeder was out on forced outage 183 hours and tree/ vegetation related duration outages 21 hours which was 11.48 % of the interruption’s duration of this feeder for the month of march.

For the month of April total forced outage resulting from vegetation was three and one out of which is transient fault. Duration of total forced outage was 160 hours and on vegetation related outage duration is 16:57 hours which was 10.36% of the cumulative outage duration .

The greatest number of tree/ vegetation related outage of eleven (11) was recorded during the month of May. Eight cases were transient faults and three were actual direct vegetation cleared from the power line. The feeder duration on forced outage came up to 367 hours and 24.60% of this resulted from tree/ vegetation cases total 90:27hour of outage period .

Five time transient fault forced outage happened in June. With a total of 89hour outage period and 50:18 hours due to vegetation related fault which stood at 56.4% of the entire outage duration.

July had only one forced outage which was as a result of a transient fault which lasted for 1:40hour Line patrol crew found no object the power line. Though the total forced interruption for the month was 638hour with 0.22% of resulting from vegetation.

UTC 33KV experienced only one forced outage due to tree/ vegetation in August. This was observed to be a transient fault. 20.83% was what the vegetation related forced outage was responsible for out of the 46hour general forced outage duration and 9:58hour due to vegetation

In September, unplanned /forced outage occurred on this feeder four times with transient ant actual vegetation encroachment occurring two time each. These four forced outages kept the feeder out for a cumulative duration of 48:35hour. The month total forced outage was 596 hour and vegetation outages represented 8.11%. In the year 2018.

October witnessed a total forced outage duration of 554hours. 22.21% of the interruption duration was due to vegetation and was for 123:04 hours.

The UTC 33KV feeder for the month of November had forced outage due to tree/ vegetation three times. One of which was transient fault and two of the interruptions were due to tree branch on the line. Outage duration of 44.35 hours due to vegetation accounted for 10.36% of the total outage duration of 428hours.

December saw a total forced outage duration of 601hours. The feeder was out on transient fault and another interruption was due to vegetation encroachment, making it two forced outages resulting from Tree / vegetation related fault. The percentage outage due to vegetation was 2.0% which was 12:01 hour outage duration due to vegetation.

MONTH OF THE YEAR	TOTAL LOAD INTERRUPTED DUE TO VEGETATION (MW)	FEEDER IN SERVICE (HRS)	FEEDER OUT ON FAULT (HRS)	DURATION OUT ON VEGETATION ENCROACHMENT (HRS)	NUMBER OF INTERRUPTION BY VEGETATION	PERCENTAGE OUTAGE DUE TO VEGETATION
JANUARY	NIL	337.0	388.0	0	0	0
FEBRUARY	7.6	420.0	240.0	32:47	3	13.53
MARCH	11.0	559	183.0	21:00	2	11.48
APRIL	14.1	559	160.0	16:57	3	10.36
MAY	51.5	376	367.0	90:27	11	24.60
JUNE	24.0	619	89.0	50:18	5	56.40
JULY	3.9	106	638.0	01:40	1	0.22
AUGUST	6.1	691	46.0	09:58	1	20.83
SEPTEMBER	19.0	110	596.0	48:35	4	8.11
OCTOBER	18.2	172	554.0	123:04	5	22.21
NOVEMBER	8.3	265	428	44:35	4	10.36
DECEMBER	10.7	143	601	12:01	2	2.00

Table 1: UTC 33KV Feeder Monthly unplanned Load Interruptions for the year 2018

Reliability indices

System reliability indices used to analyze the data collected for this work are as follows:

System average interruption frequency index (SAIFI), has to do withnumber of individual sustained interruptions in period of interest. For each of these interruptions the number of customers affected comprises the customer interruptions for the particular outage. The denominator is the total number of customers in the service area under consideration. A number of long-lasting interruptions resulted from trees/ vegetations.

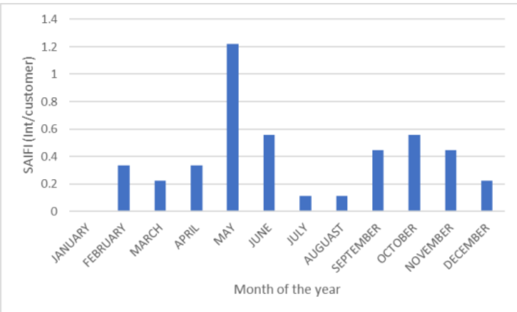
System Average Interruption Duration Index (SAIDI) resulting from vegetation for the year 2018 was 49.9077 hours/customer. Due to the frequency of interruptions witnessed on the UTC 33KV feeder resulting from tree/ vegetation encroachment. SAIDI of the supply feeder is poor. The significant of these shows the situation when the interruptions were sustained for a long duration impacting on power supply to customers on the feeder. The SAIDI can be made better by reducing the length of time of the forced outage interruptions. The SAIDI for the month of January was best which is zero, and followed by July which has SAIDI of 0.16hours/customer.

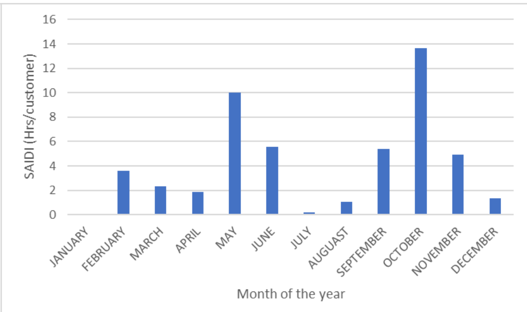
Customer Average Interruption Duration Indices (CAIDI) of UTC 33KV feeder due to tree/ vegetation encroachment was 10.9553.for the year 2018. This is the ration of SAIDI to SAIFI. The CAIDI for the month of July was 1.4000 which is next to the best figure of zero (0) observed in January. CAIDI can be improved by better and shorter repair time, faster crew response time. A customer here can be an individual, firm, or an organization who purchases electric services at one location under one rate classification, contract or schedule.

Average Service Availability Index (ASAI) can be seen on table 4 as one (1) in the monthof January which is 100%. This shows that the customers enjoyed non interruption of power supply on the UTC 33kv feeder due to tree/vegetation encroachment.

MONTH OF THE YEAR	DURATION FEEDER OUT ON VEGETATION (hrs)	NUMBER OF INTERRUPTIONS DUE TO VEGETATION	SAIFI (Int/ customer)	SAIDI (hrs / customer	CAIDI (hrs / customer)	ASAI (p.u)
JANUARY	0	0	0	0	0	1
FEBRUARY	32.47	3	0.3333	3.6078	10.8233	0.9962
MARCH	21.00	2	0.2222	2.3333	10.5000	0.9976
APRIL	16.57	3	0.3333	1.8411	5.5233	0.9981
MAY	90.27	11	1.2222	10.0300	8.2073	0.9897
JUNE	50.18	5	0.5556	5.5756	10.0360	0.9943
JULY	01.40	1	0.1111	0.1556	1.4000	0.9998
AUGUST	09.58	1	0.1111	1.0644	9.5800	0.9989
SEPTEMBER	48.35	4	0.4444	5.3722	12.0875	0.9945
OCTOBER	123.04	5	0.5556	13.6711	24.6080	0.9860
NOVEMBER	44.35	4	0.4444	4.9278	11.0875	0.9950
DECEMBER	12.01	2	0.2222	1.3344	6.0050	0.9986

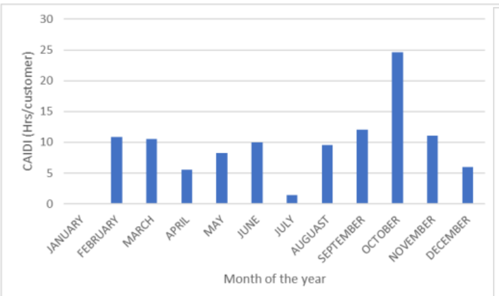
Table 2: Computed Customer Orientation Indices for the Year 2018 on UTC33KV Feeder Forced Outage Due to Vegetation Encroachment

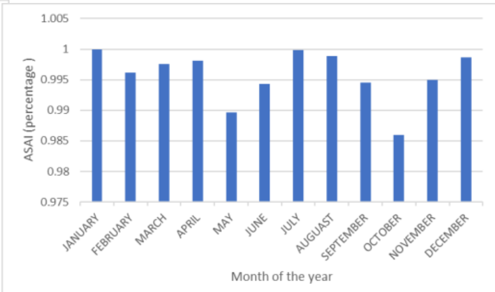




SAIFI (Interruption/customer) SAIDI (Hours/customer)

FIG 2: SAIFI FIG 3: SAIDI





CAIDI(Hours /customer) ASAI(Percentage)

FIG4: CAIDI FIG5: ASAI

V. CONCLUSION

As an electricity utility distribution power line with a record of sixty (60) unplanned outage interruption which wasdue to tree/ vegetation encroachment in the year 2018. The impact of these unplanned outage on the power line was shown in this work, how the feeder could not perform its intended function adequately. By using the descriptive method for the data collected from PHEDC and TCN.The reliability of the UTC 33KV feeder using the performance indices of SAIDI, SAIFI, CAIDI, and ASAI was analyzed. Knowing that utility performance is one of the major factors which industries look at before selecting areas in which they want to site their industries / factories. Frequent electricity interruption does not only put the customers out of supply but do result in equipment damages and production loss for industries.This have a direct and indirect consequences on the economy and nation security. ASAI which gives the fraction of time the customer has power during the reporting time of interest, was observed to be a unit in January 2018, which from the data, the feeder did not trip on tree/ vegetation encroachment in that month.The reliability of power line will improve greatly if no tree / vegetation encroachment on the line with vegetation along its corridor, as it was shown with the case of the month of January.The Major Event Day (MED) can be reduced or avoided, by monitoring of leading indicators of tree and vegetation along the UTC 33KV feeder corridor, looking at the fact that faults and interruptions due to Vegetation have significant year-to-year variation.

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