Vol-3, Issue-3 PP. 177-183 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

INVESTIGATING VEGETATION INDUCED FAULTS ON POWER TRANSMISSION LINE; A CASE STUDY OF THE IRRUA-AUCHI-AGENEBODE 33KV TRANSMISSION LINE EDO STATE NIGERIA

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ABSTRACT

Trees and other vegetation have adversely affected the operation of electric power transmission and distribution systems since the construction of the first electric lines. Vegetation intrusion causes loss of reliability and creates safety hazards. Failure to perform vegetation management has been identified as a contributing factor in wide-spread local outages, and, particularly during extreme weather conditions, to system-wide outages. Trees in direct contact with energized overhead conductors can cause interruptions by providing a pathway for the flow of fault current. When fault current is detected and interrupted by protection devices, such as fuses and re closers, an outage occurs. This electrical mode of failure and the fault pathway provided by trees has been the focus of this investigation. This research effort investigate vegetation induced fault on the Auchi -Agene bode 33kv transmission line for period of 2 years to identify the causes, the mostly affected section of that transmission line and suggest the necessary vegetation management practice to be adopted by the management to reduces the menace.

Keywords: vegetation management, re closer, fault path way, reliability, outage.

1. INTRODUCTION

An electrical power system consists of many components such as generators, transformers, transmission and distribution lines etc. However, the component with the highest fault incidence rate is transmission line due to their exposure to the environment i.e. it is the most susceptible element to experience faults. The main task of a transmission line is to maintain continuity of power supply from the generating station to the load centre, but this cannot be achieved because of line faults due lightning, storms, fog, and vegetation fall etc. The challenge trees pose to the reliability of overhead distribution systems is well recognized, as vegetation is a dominant cause of service interruptions at many utilities. The electric utility industry spends millions of naira every year performing line clearance tree pruning on both a preventive and corrective maintenance basis. High winds, especially when combined with precipitation from seasonal storms, can cause damage to electricity utility systems, resulting in service interruptions to large numbers of electricity customers. While most such power outages1 are caused by damage from trees and tree limbs falling on local electricity distribution lines and poles, major power outages tend to be caused by damage to electricity transmission lines, which carry bulk power long distances(Richard , 2009).The damage caused to overhead energy-delivery infrastructure by the structural failure of branches and whole trees is obvious, particularly during adverse weather events. Assumptions and beliefs regarding the interaction between trees and distribution lines, largely based on anecdotal observations, have guided decisions made by utility operations and engineering staff over the years. This research effort was initiated to better understand the ways in which a tree in contact with overhead conductors may cause an interruption. All tree contact with energized conductors can result in a fault; the branch provides a pathway for the flow of current. The contact begins as a high-impedance (resistance), very low current event. The vast majority of tree contacts remain this way. Only under the "right" combination of conditions does the fault pathway become more conductive. In these cases, the fault pathway evolves from high to low resistance, resulting in high levels of fault current and ultimately an interruption. The potential for a tree in contact with an energized conductor(s) is influenced by key characteristics of the distribution line involved and by the fault pathway provided by the tree. Three of the most important characteristics of the fault pathway and the potential of a tree-conductor contact resulting in an interruption are:

- **Voltage gradients**

  The electrical stress impressed on the tree or branch is a major consideration. Voltage gradient is a function of the voltage differential between two points and the distance between them. Tree contacts involving higher voltage gradients are much more likely to result in an interruption. Higher operating voltages and close phase spacing create higher gradients. Equally important to reliability, there appears to be a voltage gradient threshold below, which it is unlikely that a tree in contact with energized conductors will result in an interruption.

- **Diameter**

  The diameter of the fault pathway provided by the tree is an important consideration. Large-diameter pathways are much more conductive and therefore more likely to cause a fault than small-diameter contacts**(Alison,2011)**.

- **Species**

  There are readily observable differences in the conductivity of individual species. These differences are significant enough to warrant consideration in planning preventative and corrective maintenance tree pruning work on distribution circuits.

1.1 Vegetation and Power Lines

The industry's approach to tree-related maintenance of overhead distribution lines has come a long way from the days of "tree trimming," where trees were thought of as structures, and the goal was simply to establish and maintain fixed clearances and corrective response (or hot spotting) was the norm. Trees and other vegetation cause power system faults, outages, interruptions and other power quality problems. There are a variety of mechanisms through which this happens. Tree contacts can be abrupt and result in conductors contacting each other, either directly or indirectly, or even in line sections being torn down. Tree limbs "can fall over onto conductors, can drop branches onto conductors, can push conductors together, and can serve as gateway for animals" **(Alison,2011)**,. Vegetation can also cause slowly developing problems due to continuous growth. This phenomenon is not well documented but is believed to occur as follows:"When a tree branch bridges two conductors, a fault does not occur immediately. This is because a moist tree branch has a substantial resistance. A small current begins to flow and starts to dry out the wood fibres. After several minutes, the cellulose will carbonize, resistance will be greatly reduced, and a short circuit will occur." (**Grigsby, 2001**).

Figure 1.0: Formation of Arc between Lines

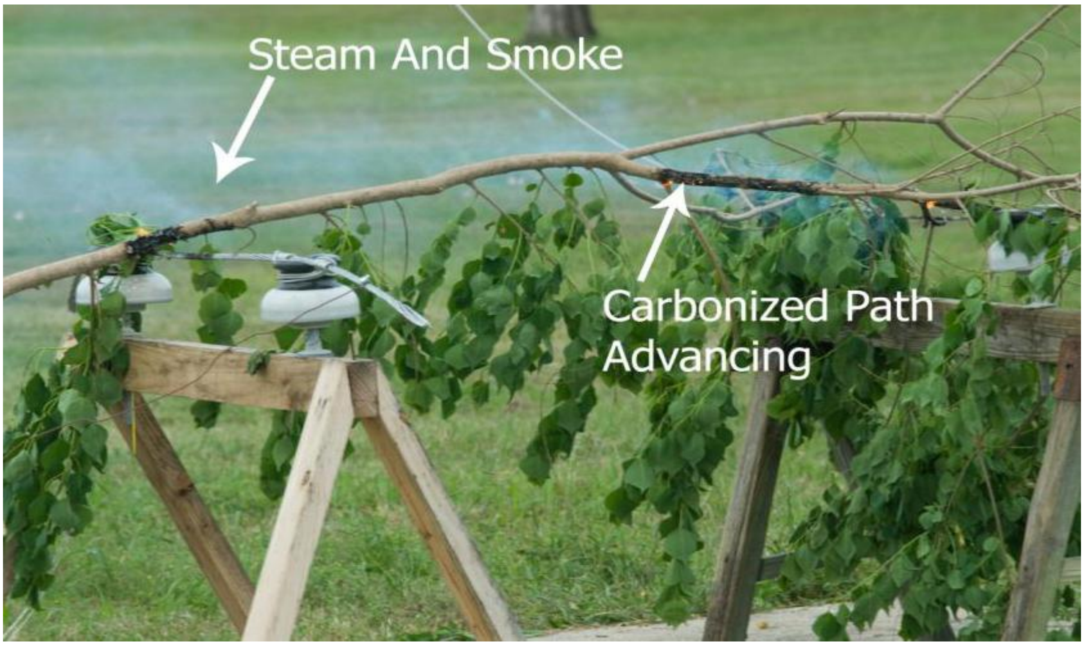

Figure 1.2: **Carbonized Path Under Bark Producing Steam and Smoke**

Experience suggests that operation of automatic circuit reclosers may temporarily relieve the faulted condition, but leave the offending branch in place, precipitating future problems. .In addition to compromising service quality and reliability, safety is a major concern. Tree contacts are a major cause of downed conductors. Research has shown that as many as one in three downed conductors will remain energized upon contact with the ground, presenting a highly dangerous public safety hazard (**Kim et al, 1995**). Additionally, vegetation in contact with lines can create dangerous touch potentials which present shock and electrocution hazards

1.2 fault evolution model

When a branch or stem of a tree comes into contact with electrical conductor(s), it provides a fault pathway between two areas of unequal electrical potential. Fault current begins to flow. The level of electrical stress and the initial characteristics of the fault pathway (branch or tree) have a major influence on what happens next (**Benner,1999)**.

High-stress gradients and relatively conductive pathways may result in increasing current flow as charring of the branch surface develops along the track of the fault. Areas of charring along the pathway are more conductive, leading to higher levels of current flow, which in turn makes the pathway even more conductive. And so it goes until at some point the gap between the points of unequal potential is bridged and a high-current fault occurs. However, most tree conductor contacts do not evolve into low-impedance/high-current faults(**Depew et al,2006)**. Often the electrical stress gradient and conductivity of fault pathway provided by the tree or branch are low. In these cases, the pathway experiences resistance heating. As low levels of current flow through the high-impedance branch, heat is generated, driving off internal moisture and reducing conductivity.

In actuality, the growth of a conductive carbon pathway and resistance heating and drying will occur concurrently. In effect, there is a "race." At the same time that a carbon path may be forming, current flowing in the branch is producing resistance heating along its length. This heating has the effect of driving off moisture and thereby increasing electrical resistance

. With relatively low-voltage gradients the current flow generating resistance heating is warming and drying the branch faster than any carbon pathway might form, thus no electrical flashover occurs. The branch simply warms and dries out, causing resistance to increase and current flow to tail off.

If, on the other hand, the voltage gradient is sufficient to generate localized dry band arcing, a conductive fault track develops. This charring results in the fault pathway becoming increasingly conductive. If the charred pathway reduces impedance faster than internal resistance, heating drives off moisture and increases impedance and the gap is bridged, resulting in a high-current fault and subsequent interruption (**Daily,1999**).

Figure 1.3: Formation of Arc Between Lines

3. 2.0 THE IRRUA –AUCHI- AGENEBODE TRANSMISSION LINE: A CASE STUDY

The above named line is a short medium –voltage overhead transmission line, being approximately 75 km long at 50Hz and 33KV in tension (SHEPHERED et al., 1970). This 150mm2 (Wolf) aluminium-conductors – steel – reinforced line has a resistance and a reactance of approximately 0.19 ohm/km and 0.34ohm/km at 50Hz and 200c, as determine from Tables. For short lines, of course, the shunt capacitance will normally be neglected, and the equivalent circuit of the line will then consist of a resistance in series with an inductive reactance .

Table 1: **vegetation induced fault on (irrua-auchi –agenebode 33kv line) between the period of feb 2012—2014**

LOCATION	NO OF OUTAGE	OUTAGE DURATION (Hrs)	NATURE OF FAULT
AGBEDE	3	19.35	bamboo tree fell on line
AYOGWIRI	1	2	branch of tree fell on line
AUCHI	6	9.22	tree fell on line
BODE LINE	2	6.1	tree fell on line
EGONO	2	8.04	branch of tree fell on line
EWU FLOUR MILL	1	10	tree fell on line
GRA	5	31.5	tree fell on line
JATTU	6	87.94	tree fell on line
OKPELLA	1	8.08	bamboo tree fell on line
SOUTH IBIE	19	232.69	tree fell on line
TOTAL=	46	414.92	

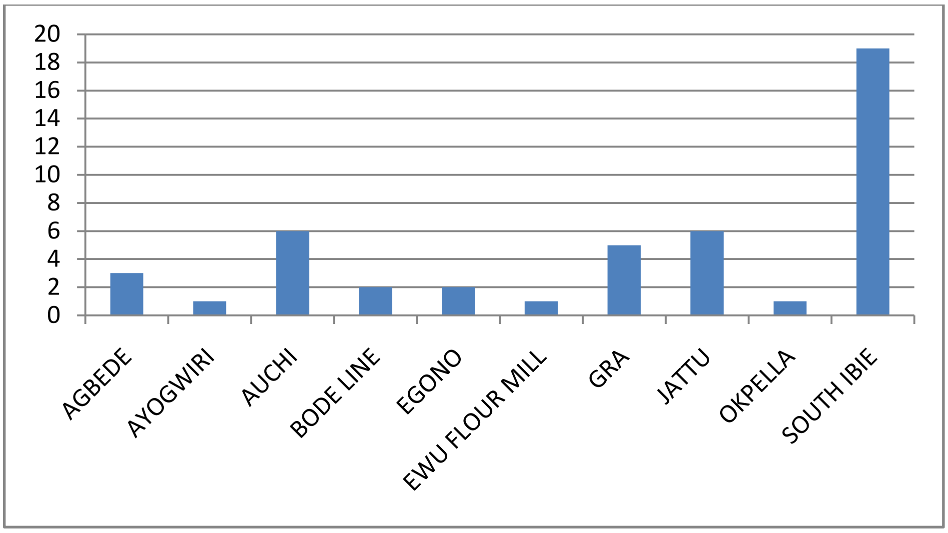

FIG 2.1 A graph of location against number of outages

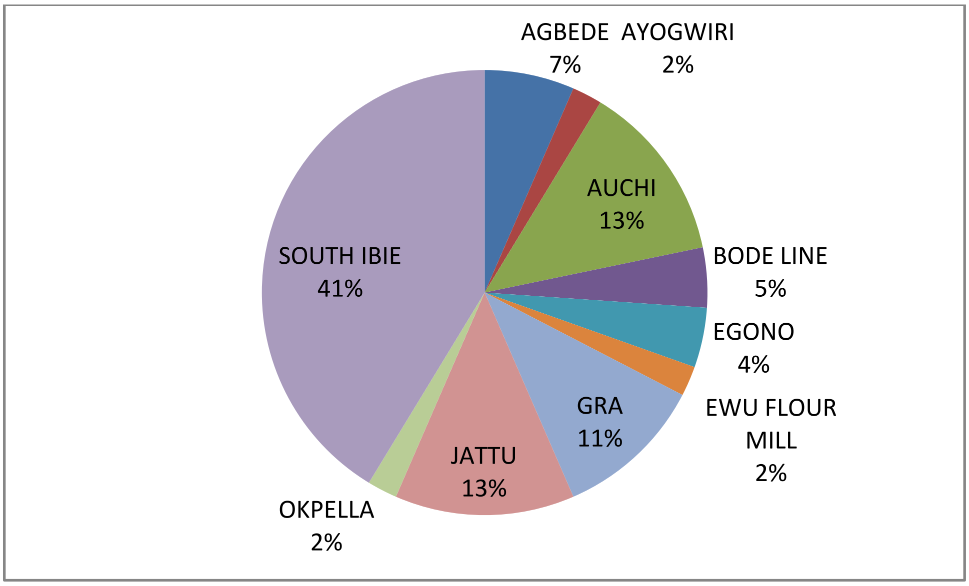

Fig 2.2: % FAULT /LOCATION

From the chart above ,it is shown that 41% of the vegetation induced fault on this line was caused on the south ibie section of the transmission line which was the highest during this period and the ayogwiri,ewu flour mill and the okpella section respectively are the least affected

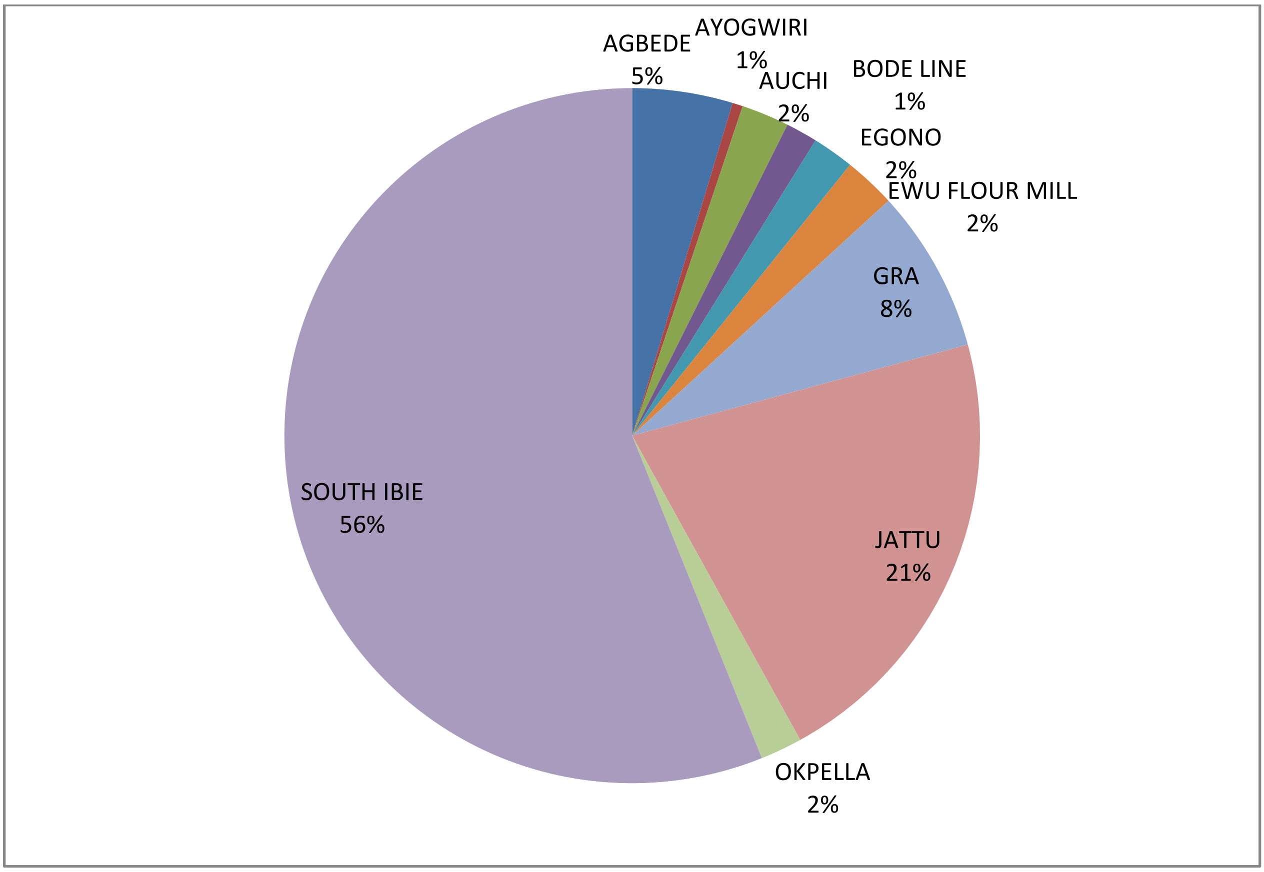

Fig2.3:% OUTAGE/LOCATION

From fig 2.3,it is shown that 56% ;more than half of the total outage experience by the cosumers on this line during the period under consideration was caused by fault on the south ibie section of the line,while the ayogwiri and bode line contribute the least;1% to the total outage experience on the line during the period.

4. RECOMMENDATION

1) Measuring and recording incipient vegetation-related outages should be encouraged
2) Hazard/danger tree identification and remediation programs will greatly improve reliability.
3) Eliminating or properly pruning overhanging branches especially in the south ibie section of the line will significantly improve reliability, particularly in storm conditions.
4) Maintaining a mandated minimum vegetation clearance (e.g. not closer than 18 inches) will likely impact overall reliability and will be cost effective.

5. CONCLUSION

During the two years period of outages analyzed by the researchers there were 46 outages at the 16-feeders substation on the line, an average of only 3 outages per feeder per year, It is well accepted and logical that vegetation intrusion causes momentary interruptions and sustained outages. As vegetation intrusion increases, reliability falls and eventually can become unacceptable. Multiple factors influence the rate at which vegetation becomes problematic: Vegetation types, rainfall, and other factors vary from feeder to feeder. Therefore, using standardized, calendar-based trim cycles to maintain acceptable reliability on all feeders necessarily means some feeders must have their trees trimmed more often than truly necessary especially at the South Ibie section of the line. Nevertheless, vigilant maintenance of vegetation clearances for power line rights-of-way are generally seen as a good practice that may help to minimize vegetation related outages

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