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PARAMETRIC MODELING OF VOLTAGE DROP IN POWER DISTRIBUTION NETWORKS

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ABSTRACT- This study presents the evaluation and parametric modeling of voltage drop in power distribution networks. The issues of voltage drop in power distribution networks has become a recurrent decimal in power distribution sector, which has avert effects on electronics appliances, which result in incessant fire out in offices and residential buildings. Benin Electricity Distribution Company (BEDC) injection substation both in Ekpoma and Benin City were investigated for a period of three months (1^{ST} February to 30^{TH} April, 2014). Data were obtained from both technical staff and prospect power consumers in that area with the help of questionnaires. Causes of various voltages drop in six power distribution injection substation sectors were obtained from both residential and industrial areas with the corresponding time (hour). Mathematical modeling was developed for voltage drop. Firstly, it was observed from BEDC power system that there were no technical reports recorded on voltage drop cases and due to lack of technical record, this aspect has witnessed a low response time from the technical sector to eradicate. It is observed that voltage drop occurrences and response time before repairs has similar exponential pattern, which justify the neglect of voltage drop. Voltage drop in both residential and industrial areas were considered.

Keywords: Causes, modeling, parametric, power system and voltage drop.

I. INTRODUCTION

The power sector has become one important basic facility or infrastructure needed by people around the world today. Power sector industry has become a tool, used to facilitate economic growth of any developing country. The power sectors generate and supply power at the desire voltage used to energize the electronics devices on our various home. Recent time, fire outbreaks have resulted from power supply in our residential buildings due to power surge from either over voltage or under voltage. Often time, due to the damage posted by this over voltage power supply, researchers has profound solution by deducing different electrical power rating fuse for different purposes to avoid a recurrence decimal of fire outbreak and damage to electrical appliances. In addition various power surge circuit breakers and stabilizers were design to content with this over voltage in power networks. Also, the issue of voltage drop was not properly attended to; it has become a normal scenario in power distribution sector in Nigeria. The voltage drop leads to fire outbreak from both home appliances and inductive load equipment. Voltage drop has negative effect on lighting illumination; excessive voltage drop can result in a reduction of equipment life, reliability, and performance. Line losses, resulting from undersized conductors, will result in increased utility costs, while simply over-sizing conductors to limit voltage drop will result in increased project construction costs [1,2,3].

Therefore the issues of voltage drop, voltage drop characteristic and resultant effects are considered in this research work. The Benin Electricity Distribution Company (BEDC) power company is serfdom with responsibility to provide service to customers at a specific voltage level, for example, 220 V or 240 V. However, due to kirchhoff's laws, the voltage magnitude and thus the service voltage to customers will in fact vary along the length of a conductor such as a distribution feeders [4,5,6,7].

A. Background Study

Voltage, electrical potential difference, electric tension or electric pressure (denoted ΔV and measured in units of electric potential: volts, or joules per coulomb) is the electric potential difference between two points, or the difference in electric potential energy of a unit charge transported between two points. Voltage is equal to the work done per unit charge against a static electric field to move the charge between two points. A voltage may represent either a source of energy (electromotive force) lost, used, or stored energy (potential drop). A voltmeter can be used to measure the voltage (or potential difference) between two points in a system; usually a common reference potential such as the ground of the system is used as one of the points. Voltage can be caused by static electric fields, by electric current through a magnetic field, by time-varying magnetic fields, or some combination of these three. Voltage drop describes how the supplied energy of a voltage source is reduced as electric current moves through the passive elements (elements that do not supply voltage) of an electrical circuit. The voltage drop in an AC circuit is the product of the current and the impedance (Z) of the circuit. Electrical impedance, like resistance, is expressed in ohms. Electrical impedance is the vector sum of electrical resistance, capacitive reactance and inductive reactance [8,9,10].

Resistive loads are loads which consume electrical energy in a sinusoidal manner. This means that the current flow is in time with and directly proportional to the voltage. Resistive load contains no inductance or capacitance, just pure resistance. Therefore; when a resistive load is energized, the current rises instantly to its steady-state value without first rising to a higher value. Resistive loads include incandescent lighting etc [10,11].

An Inductive Load is a load that pulls a large amount of current (an inrush current) when first energized. After a few cycles or seconds the current "settles down" to the full-load running current. Inductive loads can cause excessive voltages to appear when switched. Examples of Inductive Loads are motors, transformers, and wound control gear.[11.12]

A Capacitive Load is an AC electrical load in which the current wave reaches its peak before the voltage. Capacitive loads are loads that capacitance exceeds inductance. The important difference between resistive and inductive loads is that resistances do not store electrical energy, so when you interrupt the voltage across them, the current falls to zero, essentially instantaneously. Inductive loads store energy in magnetic fields that is proportional to the square of the current given in the Equation 1 below

$$E = \frac{1}{2} X\ L\ X\ I^2 \qquad (1)$$

Where E is the stored energy is in joules or watt seconds, L is the inductance in henries and I is the current in amperes. A pure inductance (most inductive loads, except for super conducting ones, also have resistive losses, so are not pure inductance) there is a different relationship between voltage and current than the simple ratio that resistors have.

$$V = L\ X\ (\frac{di}{dt}) \qquad (2)$$

From Equation 2, V is the volts across the inductor, L is the inductance in henries and di/dt is the rate of change of the current through the inductor in amperes per second [13,14].

II. METHODOLOGY

The parametric modeling of voltage drop in power distribution networks which focus on voltage drop on the distribution lines and their effects on electrical appliances in our residential houses. Literature review on voltage drop were considered, various courses of voltage drop in power distribution networks were highlighted. Data obtained by questionnaires were minister to both consumers in the distribution sector and technical power staff assigned to that injection substation transformer. Six number of injection substations were considered in two different locations, two injection substations in Ekpoma, and four injection substations in Benin City both in Edo State were considered. Voltage drop were examined in both residential and industrial areas using voltmeters. The period of investigation was six months duration. The various causes of voltage drop in power distribution system are highlighted in Table 1.

Table 1 Causes of various voltages drop in power distribution sector

S/No	Causes of voltages drop
1	Size of surface area or diameter of the conductors
2	Types of materials resistivity
3	Distance of the resident wiring cable length
4	Phase in balance
5	Neutral Failure
6	Drop of J& P fuse
7	Over loading or power load
8	linkage from poor joints and terminations

The voltage drop obtained from different injection substations and their respective occurrences, with total period voltage drop were witnessed before repairs were made and likely possible technical causes are discuss below.

A. Causes of Voltage Drop on Feeders

The voltage drop on electrical feeders depends basically on two parameters; these are; the impedance of the feeders and the current flowing through the feeders. Therefore an increase in either impedance or current will cause a corresponding increase in voltage drop.

1. Causes of Voltage Drop Due to Resistance Increase

The feeder has a higher impedance level as compared to the permissible value. A thorough inspection of the feeders reveals that the high impedance is caused by:

• Poor joints and terminations,
• Hot spots,
• Under-sized conductors, and
• Non-uniform conductor material.

- Poor Joints and Terminations**:** Poor joints and terminations is one of the contributing factors of high voltage drops on the feeder. After an inspection on the feeders, eight different positions of poor joints and termination were identified. Poor joints and terminations are resulted from loose contact between the two conductors which are joined together. When current flows through a loose contact, there will be high opposition to current flow which generates heat at that point. This leads to an increase in resistance and subsequently results to voltage drop at that point. If there are lots of such points on the feeder, then there will be a considerable increase in the summation of voltage drop at the output of the feeder.

- Hot Spots: Whenever a mechanically weak joint or termination is made, high resistance point is created. Thus the joint or termination will undergo a progressive failure. High resistance creates localized heating and since heating increases oxidation and creep, the connection becomes less tight, and further heating occurs, until the contacts tends glow. As resistance of aluminum and copper increases with respect to temperature, a higher voltage drop is realized at that point.

- Under-Sized Conductors**:** Voltage can be thought of as the pressure pushing charges along a conductor, while the electrical resistance of a conductor is a measure of how difficult it is to push the charges along. Using the flow analogy, electrical resistance is similar to friction. For water flowing through a pipe, a long narrow pipe provides more resistance to the flow than does a short wider pipe. The same applies for flowing currents: long thin wires provide more resistance than short thick wires.

- Non-Uniform Conductor Material**:** Corrosion is an important factor to be considered in the selection of conductor materials. The two types of corrosion which exhibit greatest influence on the electrical properties of a metal are oxidation and galvanic corrosion. Since most of the commonly used electrical conductors are resistant to oxidation, the latter type is the most prevalent. Galvanic corrosion, which is caused by the difference in electrical potential between two or more metals, has to be given careful consideration when selecting conductor metals.

2. Causes of Voltage Drop Due to Load Increase

The main cause of voltage drops on the feeder which is due to current increase based on overloading of the feeders. It is worth noting that voltage drop on a line varies proportionally to the current on the line given that the impedance remains constant. Current also has similar effects as it varies directly proportional to the voltage drop, thus the load on a feeder is increased, the voltage drop on the line will also increase. In some situations where there are more load in one feeder, there is need to share the load alone the available feeders, which is refer to as low "share do" it is a mean of eradicate voltage drop at the at consumers end.

B. Modeling of Voltage Drop

The major parameters of voltage drop are size of surface area or diameter of the conductors, the materials resistivity and the applied load. Let the Voltage Drop (Vd), Surface Area (SA), Materials Resistivity (R), Length (L) and Load or power consumption (p). Therefore the total voltage in a distribution lines is the summation of all these parameters.

Recall that voltage, $V = IR$ 3

Where $R = \frac{\rho L}{SA}$ 4

Let substitute Equation (4) into Equation (3)

Therefore $V = I(\frac{\rho L}{SA})$ 5

Recall, load is evaluate in terms of power, which is measure in watt

$P = IV$ 6

Therefore, $V = \frac{P}{I}$ 7

Therefore the summation of Equation (5) and (7) will result in Equation 8

$V = \sum I(\frac{\rho L}{SA}) + \frac{P}{I}$ 8

Where L represents the length of conductor in feet; while I is the current in conductor (amperes) and SA is the surface area of the conductor. Note that power consumption is also major parameters in consideration of voltage drop in power system and Voltage Drop (VD) measured in volts.

III. RESULTS, ANALYSIS AND DISCUSSION

The data obtained are presented graphically in Fig 1 to Fig 4.

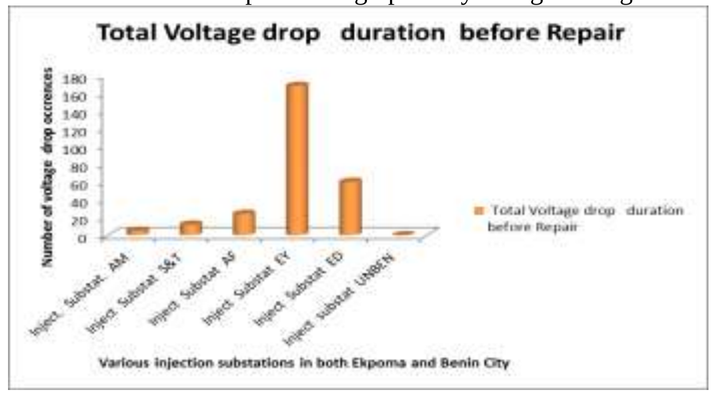

Fig1 Number of voltage drop occurrences in a month against various injection substations in both Ekpoma and Benin City.

From the above graph in Figure1, shown the number of voltage drop occurrences in a month against various injection substations in both Ekpoma and Benin City. It is observed that the injection substation in EY at Eyaen has the highest voltage drop occurrence followed by the injection substation ED at Ediaken area both in Benin City. The mean causes of voltage drop in both Eyean and Ediaken areas were due to over load of injection substation. In Figure.2, the total times in hours before voltage drop are repairs against various injection substations in both Ekpoma and Benin City. Firstly, it was observed from BEDC power system, that there were no technical reports recorded on any log books on voltage drop cases. The only technical report is on power outages and relative faults. Therefore voltage drop in power system has witnessed a low response time from the technical sector to eradicate. It is observed that voltage drop occurrences and response time before repairs has exponential distribution pattern shown in Figure 2. Also from Figure 2 the injection substation EY at Eyaen has the highest response time in hours, followed by injection substation ED at Ediaken area both in Benin City.

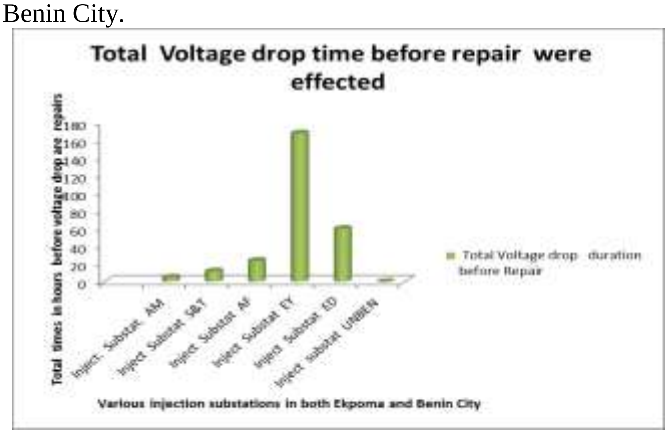

Fig 2 Total times in hours before voltage drop are repairs against various injection substations in both Ekpoma and Benin City.

Also, it is observed that voltage drop variation differ from one injection substations to another. The voltage drop with the corresponding time obtained from examine injection substation was presented graphical in Figure 3. The voltage drop variations were considered from both residential area and industrial area. It is observed in residential area that voltage from injection substation experience a gradual drop in voltage between 7.00 hrs to 16.00 hrs, while a sharp drop in voltage between 16:00 hrs to 20.00 hrs before a gradual rise in voltage were witnessed in the power distribution sector shown in Figure 3. While in Fig 4, the industrial area witnessed voltage drop decrease sharply from 7.00 -hrs to 18.00 hrs. This is due to heavy inductive load in operation on the power system during the day.

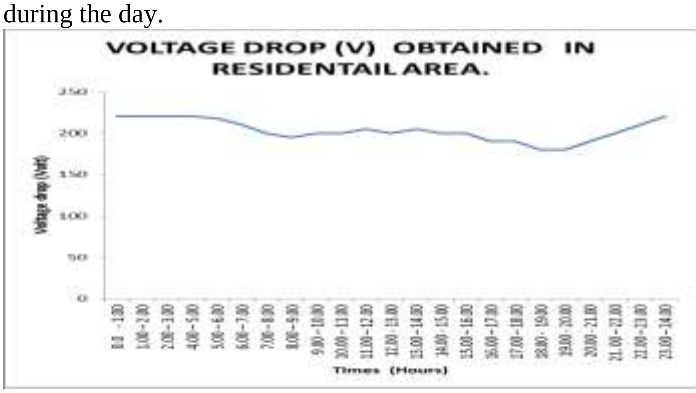

Fig 3 Voltage Drop (Volt) in residential Area against Time (Hours)

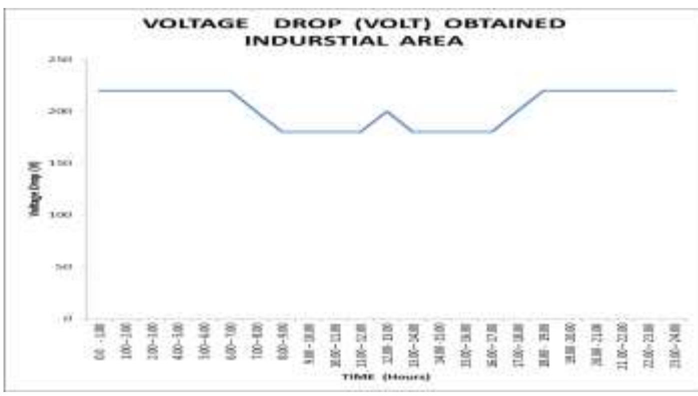

Fig4. Voltage Drop (Volt) in industrial Area against Time (Hours).

IV. CONCLUSION

Voltage drop is the reduction in voltage in an Electrical circuit between the source and load. For equipment to operate properly, it must be supplied with the right amount of power, which is measured in watts: current (amps) times voltage (volts). Incorrect or insufficient power amounts can result in negative effect on lighting illumination, reduction of equipment life span, decreases reliability, increased utility costs, inefficient operation, wasteful power usage, fire outbreak and even equipment damage. Voltage drop has become impairment in power distribution networks, while the resident as suffered neglect from the power system. Voltage drop increases with increase in temperature, decrease in diameter of the conductor and increase in load. The various causes and occurrences of voltage drop are highlighted in this study. The voltage drop profiles in both residential and industrial areas are presented. Voltage drop modeling is presented in equation and the possible solution to voltage drop.

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