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ASSESSING DISTRIBUTION SYSTEM STABILITY, VOLTAGE DROPS AND POWER LOSS CACULATIONS ON PRIMARY FEEDERS

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ABSTRACT

Electrical power production is basically of three sections: generation, transmission and distribution. The quality of electrical energy reaching the electricity consumers in Nigeria is very poor, most especially in urban areas. Efforts are made in this work to provide a method of minimizing the problems of low quality of electricity power supply in Nigeria. Analytical assessment of voltage profiles through voltage, power flows and power loss calculations o n p rimary distribution feeders will g o a long way t o assist in maintaining a stable and reliable distribution system. Using Ilorin (N.E.P.A.) distribution networks as a case study, voltage drops based on approximate and exact formulae and power losses were calculated at various loadings. Results obtained showed some primary feeders experienced voltage drop above limits of ±10% statutory value.

INTRODUCTION

A stable and reliable supply of electricity to consumers by any electric power supply authority is essential.

One of the ways to achieve standards of electricity supply is to be assessing the voltage and power profiles on the primary distribution system. This involves computing voltage drops, power flow and power losses on primary distribution feeders. The analysis in this work was done by considering the radial distribution.

Voltage drop calculation is essential for distribution lines. The consumers cannot obtain satisfactory and efficient performance from electrically powered equipment operating on voltages outside the designed values. Therefore, the analysis will go a long way to assist the distribution engineer in planning and control at all times.

Determination of p ower f lows a nd l osses are a lso i mportant t o e nsure that t he l ines a re n ot over-loaded and to know when "upgrading" or "relief" are required for a particular feeder load points.

Most of the methods used in the calculation of voltage drop on distribution lines are based on approximations [1, 2]. By this method, calculation is carried out by assuming constant nominal voltage throughout the length of the feeder. In order to minimize error in the results incurred due to approximate method the exact voltages in all segments/branches of the feeders were also considered. Variations in the two approaches were examined using t – test statistics.

MATHEMATICAL_ANALYSIS

Voltage Drop Calculations on Primary Feeders: Voltage Drop Calculations based on approximate formula:

In the evaluation of voltage drop on branches of the feeder expression 1.0 is used. [1, 2]

$$\Delta V_{ij} = \frac{(PR + QV)}{V} L_{ij} \quad \ldots\ldots\ldots\ldots\ldots \quad (1.0)$$

where, ΔV_{ij} = voltage drop along branch ij in kV

V = distribution voltage (normal) in kV

P = Active Power flow in MW along the branch ij

Q = Reactive Power flow in MVAR along the branch ij

R = branch Resistance in Ω/km/Phase

X = branch reactance in Ω/km/Phase

The expression (1.0) assumes constant nominal voltage on the feeder [2].

Expression (1.0) can be rewritten as

$$\Delta V_{ij} = \frac{S_{ij}(R\cos\theta + X\sin\theta)}{V} L_{ij} \quad \ldots\ldots\ldots \quad (1.1)$$

where, Cos θ = power factor of the load,

S_{ij} = the total power flow in MVA in branch ij.

Voltage drop calculation based on exact voltages in all branches:

If the exact or actual voltage in all branches is considered for the calculation of voltage drop, equation 1.1 becomes

$$\Delta V_{ij} = \frac{S_{ij}(R\cos\theta + X\sin\theta)}{\left[V - \sum_{k=1}^{i}\Delta V_{ok}\right]} L_{ij} \quad \ldots\ldots\ldots \quad (1.2)$$

where, $\sum_{k=1}^{i}\Delta V_{ok}$ = Summation of voltage drop in kV from the injection point or source "0" to the load point (node) k.

V = Distribution Voltage in kV.

Power Loss and line Flow calculation.

In the evaluation of power losses and line flows a long the feeder expression, (1.3) and (1.4) are used [2, 5, 6].

$$\Delta S_{ij} = \left|\frac{S_{ij}}{V}\right| |Z| \cdot L_{ij} \quad \ldots\ldots\ldots\ldots \quad (1.3)$$

and $$S_{ij} = \Delta S_{ij} + S_j \ldots\ldots \quad (1.4)$$

where, ΔS_{ij} = power loss in MVA in the branch

S_j = Total power in MVA at node j

Z = Line impedance in Ω/Km

S_{ij} = Line flow in MVA along branch i-j

V = Distribution voltage in kV.

For the purpose of this analysis, transformer losses of 1% of rated capacity are assumed for calculations. [3, 5]

COMPARISON OF APPROXIMATE AND EXACT METHODS FOR VOLTAGE DROPS CALCULATIONS, USING T-TEST STATISTIC

The approximation formula of equation (1.0) is believed to have excellent justification for a short distribution line [2] as long as there are no system imbalances, reverse in the normal direction of flow of current, dispersion of generation, heavy current loading, real power source (whether substation bus or power producer) absorbing Vars etc. [1, 2]

During abnormal conditions, such as mentioned above, or for a very long distribution line, or when the system is operating at leading power factor, it becomes necessary to use the formula (1.2) based on the exact voltages in all the branches of such feeders.[1]

Representing the results from the two approaches with populations (x_1) and population (x_2), the comparison of them can be done using statistical t – test. [7, 8]

T–Test statistic about the difference of two means

Let us represent statistically the results from the two formulae (1.1) and (1.2) by population samples of size n_1 and n_2, respectively [7]. The t – distribution [7, 8] can be used to test a hypothesis about the difference between the means of two populations if the variances of the populations are equal. [7]

If $\bar{x}_1$ is the mean of a sample of size n_1 from a normal population with variance S_1^2; and if $\bar{x}_2$ is the mean of a sample of size n_2 from a normal population with variance S_2^2; then the random variable t is given as [7];

$$t = \frac{\left|\bar{x}_1 - \bar{x}_2\right|}{S_{\bar{x}_1 - \bar{x}_2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1.5)$$

where

$$S_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}} \quad \ldots\ldots\ldots\ldots \quad (1.6)$$

and the t – distribution has degree of freedom of $n_1 + n_2 - 2$.

Decision rule (test of hypothesis):

If the calculated t is greater than tabulated $t_{\alpha/2}$; $n_1 + n_2 - 2$(where α is the significant level), then we conclude that the two population means are different. [7, 8] Or, in simpler term the formulae are different. Otherwise we conclude that the two population means are the same [7, 8] or the two approaches produce almost the same results.

RESULTS AND DISCUSSION

Figure 1 shows the schematic diagram of the existing power distribution network within the National Electric Power Authority (N.E.P.A.), Ilorin District. Power is injected through a 132kV line from Osogbo. Apart from the metropolis, Ogbomoso undertaking is fed from this injection sub-station on a 33kV busbar as shown. All existing primary distribution feeders within the metropolis are 11kV. These feeders include GRA, Adewole, Airport industrial, Offa Road, Township 1, Township 11, Kulende University / UITH and Unity. The feeders are radial in nature, the furthest load centre being about 27km from the main injection sub-station. [4]

The length and number of load points on some of these feeders raise some questions on the quality of supply enjoyed by consumers in those areas of Ilorin district covered by these feeders. Typical examples are GRA and Adewole feeders. Analysis on voltage drop, power flow and power losses were carried out using expressions 1.0 – 1.4, with balanced system loadings assumed throughout. The results are shown in Tables 1 and 2.

Calculation of voltage drops on the feeders was done using the approximate and exact formulae from the results of Tables 1 and 2. Variations in the two approached were determined using t – test statistic of 1.5 and 1.6, and this is presented in appendix 2.

Considering the entire system (networks), the t- test statistic result showed that there is no appreciable variation when the two techniques were used, even at confidence level of 95%. However appreciable errors are recorded on the two heavily loaded feeders: Adewole feeder and GRA feeders. Power losses are also higher for the heavily loaded feeders such as Adewole Township feeder 1, and GRA, even when eighty percent of the loading were considered. Also, feeders like Adewole Township 1, and GRA, for 60%, 80% and 100% loading, experienced voltage drop limits of $\pm 10\%$ statuary value on a primary feeder.

Records from Ilorin NEPA authority also showed that loadings of some distribution substation transformers (11kV / 0.415kV) on these feeders fall between 77% and 118%. [4].

CONCLUSION

Distribution system instability sets in when one or more of its primary distribution feeders experience high percentage power losses and voltage drop. In order to improve the quality of power supplied to the consumers the need to know the voltage profile in the entire buses of distribution network is very essential. Periodic evaluation of voltage drops and power losses as new alterations are made to the system loading on the distribution is very important in maintaining stable distribution systems. The t- test statistics on the results of the analysis showed that the approximate formulae of voltage drop calculation are appropriate when feeders are not heavily loaded. However, the work piece presented here showed that errors are incurred on some heavily loaded feeders when approximate formula is used to calculate voltage drops. A distribution system may appear analytically to be operating within a normal voltage profile of $\leq$ 10%, when approximate formula is used to calculate voltage drop on lightly loaded lines. The technique is deceptive when the heavily loaded lines are considered. Typical example is Township feeder II at full loads as shown in Tables 1 and 2. Conclusively, the system needs improvement to achieve better stability.

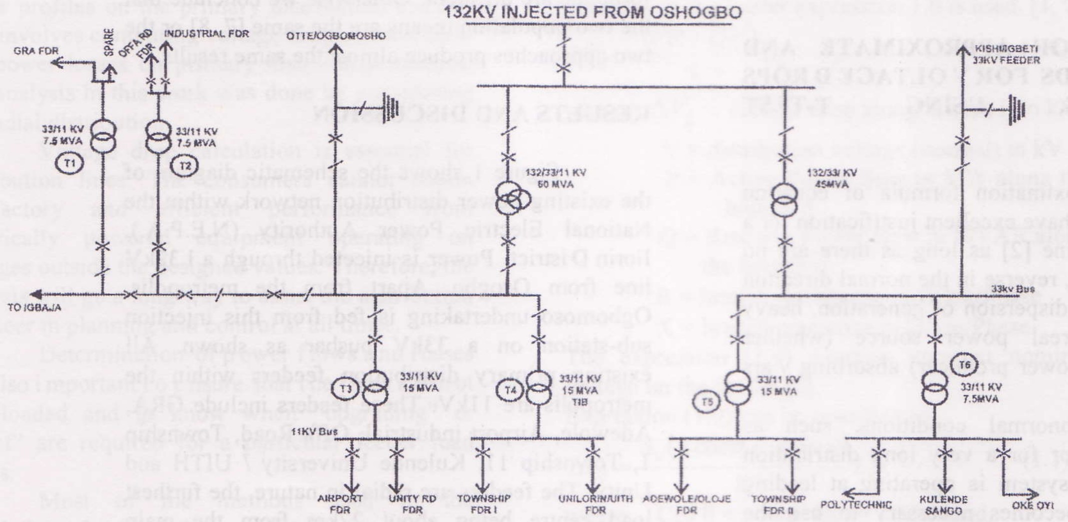

FIG. 1: ILORIN DISTRIBUTION NETWORK

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