Optimum Reliability and Cost of Power Distribution System: a case of Power Holding Company of Nigeria

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ABSTRACT

This paper presents a holistic approach towards the sustainability of power distribution system through the application of operations research evaluation technique. The approximate cost of energy loss, substation cost, feeder cost and outage cost was developed using dynamic programming technique with the aim of optimizing the costs. The optimization programme minimized the total costs of the distribution system as the objective function by determining the optima of the number locations and power of the substations, the routes of the feeders and the power losses within the network subject to a set of constraints. This study contributed significantly in analyzing the variable costs of substations.

Keywords: Power, distribution, optimization, cost, programming.

1.0 INTRODUCTION

The Electric Power Sector is one of the most important sectors to national development. The power sector is critical to the developmental reform of any country. For many years in Nigeria, the sector has been plagued by a plethora of problems. These problems included low generation capacity, poor distribution, decaying facilities and many others.

In Nigeria, this sector was represented through the years by the Electricity Corporation of Nigeria (ECN) which later metamorphosed to National Electric Power Authority (NEPA) and lately to Power Holding Company of Nigeria (PHCN). This monopoly came with the usual baggage of inefficiency and poor service delivery. Given global trends in the electricity sector it becomes imperative that in order to bring about significant improvement in the power sector a more holistic approach must be adopted towards making changes in the sector. To this end, there is a need for the optimal planning of the distribution system.

The problem of distribution system planning consists of determining the optimum numbers and locations of the distribution substations and the optimum way of connecting the load nodes to these substations through the interconnection of feeders. Solving the exact problem by using classical optimization technique is not possible because of the combinatorial nature of the problem.

The main planning approaches of the distribution system consist of the following methods:

i. *The decomposition approach in which a large optimization problem is divided into several smaller sub problems and each one is solved separately.*
ii. *The alternating policy method which compares a number of alternative policies and selects the best.*
iii. *The linear programming and integer programming methods where the constraint conditions are linearised.*
iv. *The dynamics programming method.*

In a study by [1], the numerical analysis of a multistage formulation of the distribution expansion problem was presented. The objective function was approximated without sacrificing the optimality. A complete multistage solution of the distribution expansion problem designed for practical applications was presented. The modeling and formulation were based on the natural course of progression in distribution and aligned with the procedures standard practices of the power industry. The multistage formulation was designed and implemented within a single mathematical programming algorithm. Global optimality was guaranteed within the numerical tolerances of the branch and bound algorithm without the need for heuristic or decomposition techniques. It was shown from the results that the non linear mixed integer quadratic programs for their problem could be accurately modeled as a mixed integer linear programs using a single linear function having the same minimizer. Their results indicated that the formulation reflected practical planning attributes and the optimal solution could be found efficiently.

In another study by [2] on a value based probabilistic approach to designing urban distribution systems. The outage rates and repair times were assumed in order to determine customer reliability. The optimal section length for switch placement on the main feeder and transformer loadings was determined. They concluded that a sectionalizing switch should be placed at every 0.7MW of feeder load or approximately every ¼ mile. Two feeder tie should be installed on a radial feeder with no three-phase branches and with no voltage constraints. They observed that the most essential tie, in terms of reliability was the tie located at the end of the feeder. This tie allowed the most flexibility because it can provide backup for a failure anywhere along the feeder.

Sarfi and Solo [3] made a study on Network radiality, parameter and performance heuristics in optimization of power distribution system operations. In all, they employed three types of heuristics as bases for optimization of the power distribution system operations:

i. Network radiality heuristics.
ii. Network parameter heuristics and
iii. Network performance heuristics.

The heuristic preprocessor module identified several switch closures that would reduce system losses. Network radiality and parameter heuristics identifies those switch openings that would preserve radiality and system operational criteria, respectively. Network Performance Heuristics assess the capability of a proposed operation to optimize specific objectives.

Abdulaziz and Alhabib [4] in their study on Power Network planning using mixed integer programming, formulated a power distribution planning model to solve the optimal sizing, timing, location of distribution substation and feeder expansion problems. The objective function of their model represented the present worth of costs of investment and energy losses of the system and it was minimized subject to Kirchhoff's current law, power capacity limits, voltage drop and logical constraints within the planning time horizon. A mixed-integer programming algorithm was used in the optimization. The developed model allowed for inclusion of the explicit constraints for voltage drop in its formulation. The model was used to solve the planning problems using the LINGO 7.0 software package. The obtained solutions indicated that the energy losses mainly determine the optimal feeder size, and the routing in the problems studied. Their results showed that the voltage drop constraints increase the optimal expansion cost to more realistic amounts and affected the structural evolution of the power networks expansion throughout the planning time.

In a similar study by [5] an improved mathematical model to optimize the size and locations of substations and the network routing problem was developed. The model was formulated to minimize the total cost of the network by determining the optimal of the substation locations and power, the load transfers between the demand centre, the feeder routes and the load flow in the network subject to a set of constraints. A general mathematical model for the optimization of distribution systems was improved. The model was coded using mixed integer programming which has two different algorithms: the branch and bound and the cutting plain algorithms. The optimization program minimized the total cost of the distribution system as the objective function by determining the optimal of the number, locations and powers of substation, the routes of the feeders and the power losses within the network.

In their work [6] a multi-objective optimization methodology using an evolutionary algorithm, for finding out the best distribution network reliability while simultaneously minimizing the system expansion costs was presented. They used a non linear mixed integer optimization model to obtain the optimal sizing and location of future feeder (reserve feeders and operational feeder) and substations.

In this study, the decomposition approach and integer programming method will be employed in solving the power distribution planning problem. The problem will be divided into three stages, namely; substation optimization, feeder optimization and outage cost optimization. These stages are formulated as a quadratic mixed integer programming problem and they are solved sequentially by the optimization toolbox available with MATLAB. This study is limited to power distribution in Awka South, Awka North and Njikoka Local Government Areas of Anambra State, Nigeria. It covers only the areas under the Enugu Electricity Distribution Plc which includes Abia state, Anambra state, Ebonyi state, Enugu state, and Imo state. Radial Distribution network system is used in the analysis. In radial distribution network system, electricity leaves the substation and passes through the network with no connection to any other supply. Injection stations were not considered in the study.

3.0 METHODOLOGY

3.1 Mathematical Formulation

The general optimization problem under consideration is as follows:

Optimize the objective function

$$F(x_1, x_2, \ldots, x_n) \quad (1)$$

Subjected to the following constraints

$$g_j\left(x_{1,} x_{2,} \ldots, x_n\right) \leq 0 \quad j = 1, 2, \ldots, m \text{ and} \quad (2)$$

$$x_{1,} x_{2,} \ldots, x_n \geq 0 \quad (3)$$

In the present problem, we are faced with cost minimization. The problem is structured in two basic forms: substation optimization and feeder optimization are formulated as quadratic programming problems and the outage cost optimization is formulated as a general nonlinear programming problem.

The quadratic programming problem is different from the linear programming problem only in that the objective function may include quadratic and product expressions of the decision variables. That is to say x_i and x_i. x_j (i ≠j) terms are permitted in the objective function.

The objective function of the quadratic program may be written as

$$\text{Minimize} \quad f(x) = (Cx + \tfrac{1}{2}x^T Qx) \quad (4)$$

Where

$$x = \begin{bmatrix} x_i \\ \vdots \\ \vdots \\ x_r \end{bmatrix} \quad (5)$$

$$C = [c_i \ldots c_n] \quad (6)$$

$$Q = \begin{bmatrix} q_{11} & \cdots & q_{1n} \\ \vdots & \ddots & \vdots \\ q_{n1} & \cdots & q_{nn} \end{bmatrix} \quad (7)$$

Assuming that the matrix Q is positive definite and symmetric

The constraints have the following form:

$$A_x \leq b$$

$$x \geq 0$$

Where

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix} \qquad b = \begin{bmatrix} b_1 \\ \vdots \\ b_m \end{bmatrix}$$

Where C, Q, and b are given constants.

3.2 Characterization of convex and concave function derivative

It can be shown that a function $f(x_1,\ x_2 \dots x_n)$ is convex if and only if the matrix of second partial derivatives

$H(x) = \left(\frac{\partial^2 f}{\partial_{xi}\partial_{xj}}\right)$ is positive semi-definite (8)

Likewise $f(x_1,\ x_2 \dots x_n)$ is concave if and only if H(x) is negative semi-definite.

(Note: Positive semi-definite if H(x) ≥ 0, x≠ 0

Positive definite if H(x) > 0, x≠ 0

Negative definite if – H(x) is positive definite

Negative semi-definite if –H(x) is positive semi-definite)

General nonlinear programming usually involves objective function which may not be a linear function, or some constraints which may not be linear constraints. The objective function of a nonlinear program may be written as

$Min\ f(x) = f(x_1, x_2, \dots x_n)$

$s.t \quad g_1(x_1, x_2, \dots x_n) \le b_1$

$g_2(x_1, x_2, \dots x_n) \le b_2$

$g_m(x_1, x_2, \dots x_n) \le b_m$ (9)

To solve (9), we associate a multiplier λ_i with the ith constraint in (9) and form the Lagrangian

$$L(x_1, x_2, \dots, x_n, \lambda_1, \lambda_2, \dots, \lambda_n) = f(x_1, x_2, \dots, x_n) + \sum_{i=1}^{i=m} \lambda_i\{b_i - g_i(x_1, x_2, \dots x_n)\} \quad (10)$$

Then we attempt to find a point ($x_1, x_2 \dots x_n, \lambda_1, \lambda_2 \dots \lambda_n$) that maximizes (or minimizes)

$L(x_1, x_2, \dots x_n, \lambda_1 \lambda_2 \dots \lambda_m)$

and that is the point for which

$$\frac{\partial L}{\partial x_1} = \frac{\partial L}{\partial x_2} = \cdots = \frac{\partial L}{\partial x_n} = \frac{\partial L}{\partial \lambda_1} = \frac{\partial L}{\partial \lambda_2} = \cdots = \frac{\partial L}{\partial \lambda_m} = 0 \quad (11)$$

Equation (11) can be solved by the application of Kuhn- Tucker conditions. (To apply the Kuhn-Tucker conditions, all the nonlinear programming problems constraints must be ≤ constraints. A constraint must be ≤ constraints.)

A constraint of the form

$g(x_1, x_2 \dots . x_n) \ge b$ must be rewritten as -g ($x_1, x_2 \dots x_n$) ≤ - b

For maximization problem, if f(x) =($x_1, x_2 \dots x_n$) is an optimal solution to (9), then f(x) =($x_1, x_2 \dots x_n$) must satisfy the m constraints in (9), and there must exist multipliers $\lambda_1, \lambda_2 \dots \lambda_m$ satisfying

$$\frac{\partial f(\bar{x})}{\partial x_j} - \sum_{i=1}^{i=m} \bar{\lambda}_i \frac{\partial g_i(\bar{x})}{\partial x_j} = 0 \qquad (j = 1,2, \dots n) \tag{12}$$

$$\bar{\lambda}_i [b_i - g_i(\bar{x})] = 0 \qquad (i = 1,2, \dots, m) \tag{13}$$

$\lambda \geq 0$ (t= 1, 2…m)
(14)

For a minimization problem, if $\bar{x} = (\bar{x}_1, \bar{x}_{2,} \dots \bar{x}_n)$ is an optimal solution for (9), then $\bar{x} = (\bar{x}_1, \bar{x}_{2,} \dots \bar{x}_n)$ must satisfy the m constraints in (9) and there must exist multipliers
$\bar{\lambda}_1, \bar{\lambda}_2, \dots \bar{\lambda}_m$ satisfying

$$\frac{\partial f(\bar{x})}{\partial x_j} + \sum_{i=1}^{i=m} \bar{\lambda}_i \frac{\partial g_i(\bar{x})}{\partial x_j} = 0 \qquad (j = 1,2, \dots n) \tag{15}$$

$$\bar{\lambda}_i [b_i - g_i(\bar{x})] = 0 \qquad (i = 1,2, \dots, m) \tag{16}$$

The Kuhn-Tucker conditions are necessary conditions for a point to solve (9). If the g_i ($x_1, x_2, \dots, x_n$) are convex functions and the objective function $f(x_1, x_2, \dots, x_n)$ is concave (convex), then for a maximization (minimization) problem, any point satisfying the Kuhn-Tucker conditions will yield an optimal solution to (9).

3.3 Problem Formulation

The distribution system planning problem is studied to select the optimum substations, optimum number of feeders and the optimal system node reliability such that the total system cost is minimum, while the voltage and capacity limits are not violated. The objective function may generally be stated as

$$\text{Minimize } C_{Total} = C_s + C_f + C_o \tag{17}$$

Where C_{total} *is the total costs to be minimized*

C_s *is the cost associated with substations*

C_f *is the cost associated with feeders*

C_o *is the cost incurred due to outages*

3.3.1 Substation Optimization – Stage 1

The cost associated with substations can be categorized into two types fixed costs and variable costs. Fixed costs include the cost of transformers, installation cost, depreciation of the equipment and taxes. Variable costs are the operation costs and maintenance costs. Also to be considered in the formulation of the substation optimization model is the resultant power flow through fth feeder association with the substation, the unit cost of power loss for fth feeder and resistance of the fth feeder.

Therefore the problem of substation optimization may be stated as

$$C_s = \sum_{i=1}^{m} C_i S Y_i + \sum_{i=1}^{m} \sum_{j=1}^{n} \partial_{ij} \, (I^2 R Cos\theta) ij + \sum_{f=1}^{n} (I^4 R^2 cos^2\theta)_f I_f R_f \quad (18)$$

Such that

1. *1≥ $Y_i \geq 0$ upper and lower boundary for substation selection variable.*
2. *$P_k+, P_k-, P_k \geq 0$ No upper boundary and zero lower boundaries for power flow variable.*
3. *$\Sigma^L K = 1,\ P_K = PD_i, i = 1, 2 \dots N,$ power flow balancing at node i.*
4. *$\Sigma^L K = 1 \quad P_K = \leq Q_{jmax}\ Y_j$, j = 1, 2… M, maximum substation capacity.*
5. *$P_k \leq P_{kmax}\ Y_j$, direct linked substation maximum feeder capacity.*

3.3.2 Feeder Optimization - Stage 2

After determining the optimum number and locations of substations, we can then find the optimum number of feeders to be connected to each substation. To achieve this, we need the route length of the feeders and the cost of all the feeders in relation to the substations. The problem of feeder optimization may be stated as:

$$C_f = \sum_{i=1}^{m} C_i S Y_i + \sum_{i=1}^{m} \sum_{j=1}^{n} \partial_{ij} \, (I^2 R Cos\theta) ij + \sum_{f=1}^{n} (I^4 R^2 cos^2\theta)_f I_f R_f + \sum_{f=1}^{n} F_f X_f \quad (19)$$

Such that

1. $Y_j = 1,$ *selected substation(s)*
2. 1≥ $X_K \geq 0$ *upper and lower boundaries for substation selection variable.*
3. $\Sigma^L K = 1,\ P_K = PD_i, i = 1, 2 \dots N,$ *power flow balancing at node i*
4. *4. $\Sigma^L K = 1 \quad P_K = \leq Q_{jmax}\ Y_j$, j = 1, 2… M, maximum substation capacity.*
5. $P_K \leq P_{Kmax} X_K,$ *maximum feeder capacity.*
6. $\Sigma^L K = 1, X_K \leq U_{imax} Y_j$, j = 1, 2… M, *maximum number of direct linked substation feeder.*
7. $\Sigma^L K$=1 $X_{ik} \geq 1, i = 1,2, \dots, N,$ *radiality satisfaction at lode node i.*

3.3.3 Outage Cost Optimization – Stage 3

The outage cost is a responsible indicator for the power supply availability in a distribution system node. If the reliability is improved, the value of outage cost falls, and if it deteriorates, the value of outage cost rises. The outage cost varies depending on the duration of the outage considering the outage cost the general problem may be stated as

$$C_T = \sum_{i=1}^{m} C_i S Y_i + \sum_{i=1}^{m} \sum_{j=1}^{n} \partial_{ij} \, (I^2 R Cos\theta) ij + \sum_{f=1}^{n} (I^4 R^2 cos^2\theta)_f I_f R_f + \sum_{f=1}^{n} F_f X_f + \sum_{i=1}^{p} PD_i \, n_i t_i \quad (20)$$

Such that

1 Y_j = 1, *selected number of substation(s)*

2 X_K = 1, *selected number of feeder(s)*

3 Pij= *Power flow in the branch between nodes i and j*

4 $\Sigma^L K = 1$ P_K $=PD_i$, *j = 1, 2… N, power flow balancing at node i.*

5 $\Sigma^L K = 1$, $X_K \leq U_{imax} Y_j$, j = 1, 2… M, *maximum number of direct linked substation feeder.*

6 $\Sigma^L K = 1$, X_K = qd_i, i = 1, 2… N, *radiality satisfaction at load node i.*

7 $P_K \leq P_{kmax} X_K$, *maximum feeder capacity*.

8 $\Sigma^L K = 1$ $P_K = \leq Q_{jmax}$ Y_j, j = 1, 2, …, M, *maximum substation capacity*

9 *Short feeder fault rate ≤ long feeder fault rate*

10 *Short feeder repair time ≤ long feeder repair time*

Assumptions

1. Feeder conductor type ACSR
2. Max capacity of each feeder 10MVA
3. Resistance of the Kth feeder = 0.6410 52/KM
4. Outage cost = Energy cost = N7.00 per KWH
5. Feeder investment cost = 0.75million Naira/KM
6. Fixed cost for substation: for completion of substation 2 x 30/40MVA = N700 million 133/33kV transmission substation

   i.e. 70MVA = 700Million

   10MVA = 100Million

   :. 120MVA = 1200Million
7. *The system is energized full time in a day and 8700hrs in a year*
8. PD_i, *i = 1, 2, …, N, are the maximum number of load demand nodes in MVA*
9. $P_k = IVCos\theta$
10. R = $\frac{e}{A} x L$

3.4 The cost of Electrical Energy

The cost per kilowatt hour of the electrical energy generated depends on the investment in the plants, distribution system, maintenance costs and cost of operation. If reliability is required, the costs of reserve systems increase the cost of the energy. Variable load conditions change the cost of energy produced under different conditions. If the load conditions differs too much from the ideal the cost of the energy increases.

The cost of energy can be broadly divided into two parts. A portion of the cost that is dependent on the installed capacity of the system and is independent of the amount of energy available. The other part depends on the available energy. These costs that depend on the installed capacities are fixed costs and variable costs depend on the available energy.

The fixed costs of a substation include the cost of land, the cost of building and equipment, the cost of installation and the cost of designing and planning the substation interest on capital, taxes and depreciation of equipment are equally considered in the fixed cost of a substation. The variable cost deals with the operation costs, maintenance costs and costs of consumable materials.

In this study, the cost of equipment installation cost, depreciation of equipment, taxes, operation cost and maintenance cost are considered.

4.0 RESULTS

4.1 Solution of Substation Optimization

The substation optimization problem is started with four feasible substation locations as possible candidates for optimum locations. The substation optimization problem needed two iterations where, in the first iteration Enugu Agidi substation is eliminated and in the second iteration Abagana substation is eliminated. Thus, selecting Nibo substation which already exists and Agu Awka substation as the optimum substations with total capacity of 150MVA. The results obtained from the substation optimization are shown in Table1. The optimization was done in Matlab. This process is repeated until the required number of substation is eliminated which is checked by verifying the condition:

∑Capacity of the Selected Substation = Total Demand + Capacity Margin

The solution of the substation optimization is shown in Table 1 below:

Table 1: Results obtained from substation optimization

Iteration	Selection variable	Substation fixed selection variable value after solution	Available system capacity (MVA)
1	*$Y_1 = 1$ $Y_2 = 0.4703$ $Y_3 = 0.3528$ $Y_4 = 0.4383$	$Y_1 = 1$ $Y_2 = 1$ $Y_3 = 0$ $Y_4 = 1$	210
2	$Y_1 = 1$ $Y_2 = 0.5710$ $Y_4 = 0.4980$	$Y_1 = 1$ $Y_2 = 1$ $Y_4 = 0$	150

* Nibo substation exists already

4.2 Solution of Feeder Optimization

The feeder optimization problem determines the optimum radian configuration of the distribution network. The optimization process started by formulating a quadratic programming problem with the optimum substation locations and the associated feeders obtained by the substation optimization problem. This process is adopted because the radical configuration of the feeder through each selected substation can be obtained easily during alteration process in MATLAB optimization tool box.

After each quadratic programming solution of the feeder optimization problem one or more feeder are eliminated by forcing the value of $X_K{}^{'s}$ to zero value. This process is repeated until the optimum radical network is obtained. The feeder optimization is obtained. The feeder optimization problem therefore can be relaxed to assume any value from '0' to '1' which however actually will be '0' or '1'. A '0' or '1' value to X_K is forced after the solution of the quadratic programming problem is obtained. The solution of the feeder optimization is shown in Table 2.

Table 2: Result obtained from feeder optimization

Iteration	**Minimum selection index**	**Feeder eliminated**
First	0.3	X_2, X_3, X_7
Second	1.0	X_6,

4.3 Solution of the Outage Cost Optimization

The system node outage indicates component when it is not available to perform its intended function adequate due to some event directly associated with the component. The outage cost optimization needs single iteration. The solution of the outage cost optimization is shown in Table 3.

Table 3: Outage and failure rate of power supply system.

t_i = Duration of interruption (minutes)

n_i = Failure rate

Month	**t_i (minutes)**		**n_i**	
	2009	**2010**	**2009**	**2010**
Jan	485	500	97	40
Feb	410	480	82	32
March	470	520	94	46
April	395	430	79	71
May	550	244.3	110	82
June	445	210	89	86
July	375	210	75	60
Aug.	440	220	88	70
Sept.	485	250	97	85
Oct.	490	430	94	70
Nov.	485		97	
Dec.	480		95	
Total	**5510**	**3494.3**	**1097**	**642**

Source: PHCN Awka Business Unit, Key performance indicating System (KPI) Year 2009 to 2010.

$$t_{2009} = \frac{5510}{60} = 91.83\ hours$$

$$n_{2009} = 1097\ times$$

$$t_{2010} = \frac{3494.3}{60} = 58.24\ hours$$

$$n_{2010} = 642\ times$$

The result was employed in the optimization of total cost minimization.

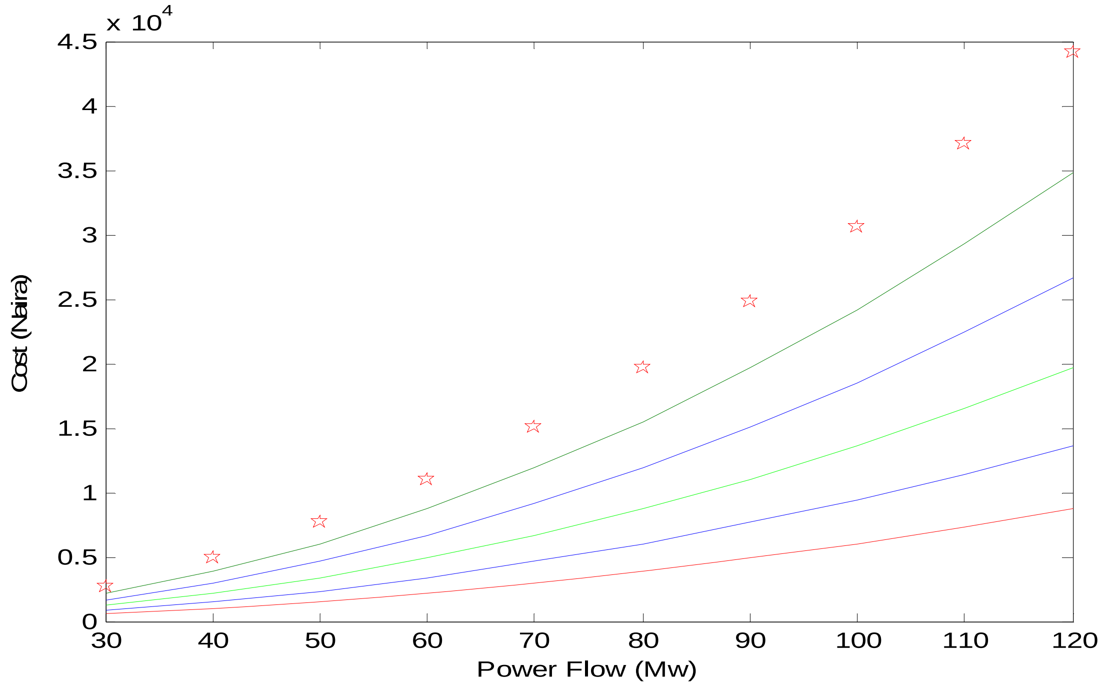

Fig 1: Plot of cost vs. power flow for various power factors

Figure 1 shows the plot of Total cost of power distribution in Awka Business Unit against power flow for various power factors of 0.4 to 0.9.

Equation (20), which gave the total cost of power distribution, was used in plotting figure 1 in MATLAB software at varying power factors. Equation (20) minimized the total cost of power distribution subject to the following constraints: power demand constraints, power capacity constraints, voltage drop constraints and logical constraints. The total cost of power distribution in Naira obtained from stage III optimization is One billion two hundred thousand Naira.

The final solution indicates that an efficient and cost effective power supply can be achieved in the case studied by establishing a transmission substation of 120MVA capacity in Agu Awka. The sub-station would be fed through the turning-in-and-out of the existing Onitsha-Oji River 132KV single circuit line. The proposed transmission substation would be three 33KV feeder lines and three 11KV feeder lines. The three 11KV feeder lines would serve Awka Township and environs. Two of the 33KV feeder lines would fed 33/11KV injection substations at Abagana and Enugu-Agidi respectively. These two proposed injection substation would serve Abagana, Enugu-Ukwu, Nawfia, Abba, Ukwuli, Nneogu, Awkuzu, Enugu- Agidi and their environs. The remaining 33KV feeder line would fed Nibo transmission substation in event of emergency, the establishing of the new substation will eliminate load shading problems and improve power supply.

5.0 REFERENCES

[1] Varizi M., Tomsovic K., & Bose A., (2004). Numerical Analysis of a Directed Graph Formulation of the Multistage Distribution Expansion Problem. IEEE Transaction on power delivery, 19, (3).

[2] Chowdhury A. A. & Custer D.E., (2005). A valued-based probabilistic approach to designing urban distribution systems. Electrical Power and Energy System 27.

[3] Sarfi R.J., & Solo A.M.G. (2002). Network radiality, parameter and performance heuristics in optimization of power distribution system operations. Part 1: Crip rule base, Electrical power and energy systems 24.

[4] Abdulaziz, U.M.A & Alhabib H.I, (2010). Power Network Planning using mixed-integer programming, JKAU: Engineering Science, 21, (2).

[5] Tủrkay B. (1998) Distribution System Planning using mixed Integer Programming, Elektrik, 6, (1).

[6] Ignacio J.R. & Jose L.B. (2001). Reliability and cost optimization for Distribution, Network Expansion using an Evolutionary Algorithm, IEEE Transactions on power systems,.16(1).