Global Journal of Engineering Science and Research Management

SHORT TIME ENERGY FORECASTING FOR XYZ ELECTRICITY DISTRIBUTION COMPANY USING FUZZY GOAL PROGRAMMING

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Abstract
In this paper, an optimal electricity allocation model (OEAM) was developed for efficient energy consumption. This was done by constructing a weighted mini sum fuzzy goal programming model where the membership functions (of the objectives) are considered as fuzzy goals and weights are introduced to the under deviational variables . In the achievement function, the under deviational variables were minimized. The results obtained showed a very good reflection of the previous energy consumption patterns in the districts. The objective function minimized gave a value of 0.000 which is a global optimum solutions, and infeasibilities zero. In the period under review, the over deviational variable values were 1.247200KWH for energy and N0.60k for revenue generation. A projection based upon the Oshogbo power control station of 10% was performed for the year 2020 and the total energy requirement in the next six years for the zone is 290,268,416.20kwh. The use of the electricity allocation model is recommended for implementation in the XYZ Electricity Distribution Zone and other electricity distribution Zones.

Introduction
Electricity supply in Nigeria is done centrally by hydro and thermal generating stations with high capacities. The main operative in Nigerian electricity power stations is the Power Holdings Company of Nigeria (PHCN) PLC which was formed in April 2005 that gave rise to 18 fresh companies which were formed for confirmed production and sharing and to guarantee effective, efficient and stable power supply; however the change have only been superficial, There is only a slight enhancement in the delivery of power in Nigeria.

Trying to get a hold of the severe electricity scarcity, several state governments have resolved to the founding of Independent Power Production (IPP) companies to increase power generation.

About 2 to 5% of the capacity of the national grid contributed by Independent Power Producers (IPP) (NESCO, Shell, AES-Lagos, Bayelsa state gas turbine and Ajaokuta steel company) all these private producers sell power to PHCN PLC for delivery and allocation to customers, while the other balance of electricity requirement in the country is by personal generating sets (Ismail, 2006)

In the quest for effectual electricity delivery in Nigeria, the PHCN PLC have adopt the Geoinformation Technology in the managing of its equipment for provision of sufficient electricity to the resident, industrial and commercial area in the country. Due to the necessitate to put into operation Geographical Information System, (GIS) in power sharing production, PHCN PLC is partnering with Hafmani Nigeria Limited, a GIS and Mapping Consultant firm (Olaniyi and Usman, 2006).

The interest in the distribution of electricity in XYZ Distribution Zone arose as a result of the scare supply of energy by Power Holding Company of Nigeria (PHCN) PLC in Nigeria which ultimately affected the quantity of energy delivered to the zone and the problem of low voltage supply to certain areas within the zone are of concern.

This study is worth pursuing because it might address how the scare electricity transmitted to XYZ Distribution Zone would be fairly distributed and the problem of low voltage supply may be resolved.

The need for this research cannot be overemphasize since supply of adequate, reliable and economically priced power supply is vital for the socio-economic growth and development of any nation. It has been observed that the gross domestic product (GDP) growth rate of a nation has a direct relationship with the growth in the per capita electricity consumption.

The development of the various sectors of the economy, such as industry and commerce, agriculture, health, education, information, banking, tourism, etc depends heavily on reliable, adequate and economically priced power. However, in rapidly developing economies where power is in short supply with increasing load demand from consumers the development of afore mentioned is very poor. Where the power need exceed what the generators can manage, generator operators have employ means of saving the power generating plants from harm this has resulted in poor quality of electricity been given out from the generators.

Global Journal of Engineering Science and Research Management

In certain instances, with the interpretation of the system operation, “operator sequential load distribution and load allocation patterns are adopted”. These leads to supplying interrupted quality electricity to customers, it is also unpredictable and does not allow the recognition of any pattern of allocation for the consumers to plan adequately (Babalola, 2009).

Determining energy requirement is a very important process that is widely used and needed in many electricity distribution companies. The interest in this area is not new; it started many decades ago. Very good and important progress has been achieved since then. Several techniques, artificial neural network, Goal programming, Linear programming are being implored in determining the energy requirement of power system in developed economy with stable political system where there seems to be a high degree of certainty in load demand.

The procedure of finding out the energy need is complex and entails lots of calculations. Together with the constant enhancements on the electricity infrastructures and the enhancements that have been completed on the models of forecasting/ determining energy requirements are making the breach between the good outcome and the good performance lesser and lesser.
In spite of all the progress that has been achieved so far, the use of an electricity allocation model that considers uncertainty and imprecision in its model formulation while simultaneously maximizing profit and energy transmitted of a developing economy electricity distribution like Nigeria has not been implemented.

This paper discusses the improvement of weighted goal programming by hybridizing it with fuzzy logic in the model formulation which minimizes the under deviational variables. The problems associated with the electricity industry in Nigeria and how these problems affects development in Northern Nigeria is discussed in section two. In section three the review of relevant literature of mathematical optimization models for energy was made. The model development of weighted mini sum fuzzy goal programming is presented in section four. In section five, the sources of data were mentioned, the total available energy transmitted and the total revenue generated were presented. The results were presented in section six. In section seven the results were discussed and projection made based on the 10% projection rate of the Oshogbo power control station in Nigeria. In the concluding remarks, the negligible deviation recorded from the results and the energy projection value were stated.

Problem Description

The problem of low and inadequate electricity supply in Nigeria has only increased in magnitude from the late eighties to date. This has led to the collapse of many industries. The problems of unemployment, underdevelopment, very high dependence on the government for white collar jobs, and robbery are but consequences. Over dependence on imports of goods and services into Nigeria, low meaningful growth and development in Nigeria to mention but a few.

The government of Nigeria has made tremendous efforts to maintain the already existing power generating plants, the problem of increasing energy demand by consumers has increased urgency in building new power plants by Independent Power Producers (IPPs) and the upgrading of the existing power plants by PHCN PLC because of the socio-economic importance of electricity in the country, yet the problem of shortage in electricity supply in Nigeria has persisted.

The increase in customer population is also critical to the success of PHCN PLC as it has direct relationship with profit generation and energy demand. Another important objective is the satisfaction of her customers by supplying the required voltage.

This research work tries to addresses the problems that were generated as a result of unstable and inadequate electricity supply in North West of Nigeria by satisfactorily distributing the available electricity supply to the XYZ Distribution Zone. The unpredicted electricity distribution in Nigeria has demonstrated a presence of several distribution objectives and continuous shifts in the priorities of these objectives. The realization of the multiple natures of the electricity distribution objectives suggest that evaluation and distribution of electricity supply might be conducted on the basis of a multi-objective analytical framework. The concurrent optimization of all objectives is usually impracticable, so the achievement of objectives and the fulfillment of constraints are made bendable. Goal programming (GP) is a practical technique for decision-makers to consider at the same time many goals in order to discover an acceptable solution and GP has been proven to be one of the most dominant methods to solve multi-objective programming problems. When features, objectives or relationships in a problem’s formulation cannot be affirmed with exactness, we work in fuzzy goal programming (FGP) (Trzaskalik and Michnik, 2002).

Thus there is the need to design a mathematical model that will contribute to the effective and efficient utilization of the electricity and project possible energy requirement. This will by extension improve the electricity supply in XYZ Distribution Zone and Nigeria in general.

Global Journal of Engineering Science and Research Management

Reviews of Mathematical Optimization Models for Energy

Load forecasting is the method of determining the quantity of electric energy of an area and/or transmission system over a known period of time (Chen et al., 2001). Konni and Ochagwuba (2014) used fuzzy and Monte-Carlos Methods to model a Long-Term Load forecast for Nigeria Power System and reported that the forecast energy for Nigeria Power System excluding suppressed demand that is demand not met is 19,204MW for the year 2020 and the maximum energy is 24,234MW. Khodr (2002) formulated a mathematical programming problem of non-dependent electricity production schemes in industrial power systems taking into account investment costs, fuel costs, operation and maintenance costs, power balance, maximum and minimum limits on the generated power of the units along with dependability with attention to details, such as the lack of the production design. These considerations comprise postulations made and simplifications executed to obtain a precise enough linear representation. The problem was solved using a conventional branch and bound algorithm for linear-integer programming yielding the optimum number of units, as well as the corresponding size and type. Results were presented for application of the proposed methodology to a real case of an industrial power system. The technique has proven to be a valuable tool for planning engineers.

According to Hayashi, Funabashi and Okon, (2006) the well-organized supply of electricity is significant in the electricity distribution system linked to by distribution type electricity sources. Appliance of current process in optimization technology of the power system has been established.

The research work considered situations were certain parameters are improved in respect to quality, time, and cost.

Leshchinskaya (2008) presented procedures of many-criteria optimization of the parameters of an industrial system. The methods were formed for 10 to 110kv electricity provision systems with consideration to doubt of part of the preliminary information. The proposed methods were established by resolving several problems of finding most favorable parameters of electricity supply systems both for countryside and metropolitan areas.

According to Yuuji (2001) the most excellent combination of electricity generation plants means most favorable mixture rate for infrastructure of thermal electricity generation, hydroelectric and atomic electricity production, etc. Several corporations integrate the design of most excellent combination in the planning of their electricity generation schemes. The work only considered the mix of power plants.

Jebaraj et al., (2008) discussed that the energy requirement of India is rising quickly due to improvements in the agricultural, industrial, commercial and transportation sectors. The enhanced way of life and rise in residents are other reasons for the swell in energy requirement. They said India has made fast development in the improvement of electricity generation, with capacity rising from almost 1,700MW in 1950 to practically 127,000MW in 2006. However, the need has only constantly increased. An energy representation would make possible the successful utilization of renewable energy sources for electricity generation in India. The diverse situation to best use the available bio-energy resources to enhance the value of life in India was presented and argued.

Wai Kuan et al., (2005) argued that in order to retain reliable and financially viable electricity supply, the preservation of electricity plants is becoming more and more significant. Representation that allows Ant Colony Optimization (ACO) algorithms to be applied to power plant maintenance scheduling optimization (PPMSO) problem was formulated and tested on a 21-unit case study. The outcome achieved point out that the performance of the two ACO algorithms examined were considerably enhanced than a number of the other meta-heuristics, like genetic algorithms and simulated annealing which was used on identical study earlier. Though these works are similar to our research work in the aspect of reliable and economic electric power supply, they differ in the techniques used, the units of case study, and the location of the research.

Model Development

The model optimizes and selects the appropriate energy distribution option for the zone based on some factors such as energy transmitted, energy received, and energy billed revenue generated and minimum energy requirement for each district. The objectives of the model are maximizing energy transmitted and maximizing revenue generated (maximizing profit). The other factors are used as constraints in the model. The mathematical representation of the model is given by the following equations:

Global Journal of Engineering Science and Research Management

$$\max : z_1 = \sum_{i=1}^{m} x_i (\sum_{j=1}^{n} D_j) \quad (i)$$

$$\max : z_2 = \sum_{i=1}^{m} x_i (\sum_{j=1}^{n} R_j) \quad (ii)$$

subject to:

$$\sum_{i=1}^{m} a_i x_i \le b_j, \; j=1 \text{ to } n \quad (iii) \qquad (1)$$

$$x_i \ge 0, \; i = 1, 2, 3, ..., m. \quad (iv)$$

$i = 1, 2, 3, ..., m$ *represents number of business units, and*

$j = 1, 2, 3, ..., n$ *represents number of months.*

Where in equation (1), (i) and (ii) are the multiple objective functions, (iii) are the constraints and (iv) is the nonnegative condition. Where D_j are the energy transmitted to each district, R_j are the revenues generated from customers billed in each months, a_i are the energy billed monthly by various business unit in the different district, b_j are the available energy for transmission to each district monthly and x_i are the monthly district energy allocation to be determined.

However, it may be difficult to determine the precise goal value of each objective, since only some partial information is known. To incorporate uncertainty and imprecision in the model formulation, the fuzzy set theory, initially proposed in *Zadeh (1965)* was introduced in the decision making problems, where aspiration levels of objectives are assigned in an imprecise manner. According to the fuzzy set-based theory, the imprecise objectives and limitations are represented by the associated membership functions presented in (*Bellman and Zadeh, 1970)*.

Now, let the aspiration levels be g_1 *and* g_2 for energy and revenue maximizations respectively. Let t_1^u *and* t_2^u denote the tolerance ranges (subjectively chosen constants of admissible violations) for the respective aspiration levels.

Assigning aspiration levels g_1 *and* g_2 to energy and revenue objectives respectively, the fuzzy goal programming (FGP) model of the distribution company's present allocation is formulated in equation 2.

Find $X = (x_1, x_2, x_3, ..., x_m)$

so as to satisfy:

$$\sum_{i=1}^{m} x_i (\sum_{j=1}^{n} D_j) \precsim g_1$$

$$\sum_{i=1}^{m} x_i (\sum_{j=1}^{n} R_j) \precsim g_2 \qquad (2)$$

subject to:

$$\sum_{i=1}^{m} a_i x_i \le b_j, \; j=1,2,3,...,n$$

$$x_i \ge 0, \; i = 1, 2, 3, ..., m.$$

Since t_1^u *and* t_2^u are the tolerances limits for the achievements of the desired aspiration levels g_1 *and* g_2 of the fuzzy goals in (1) then the corresponding membership functions take the form:

Global Journal of Engineering Science and Research Management

$$\mu(z_k(x)) = \begin{cases} 1 & , \text{ if } z_k(x) \le g_k, \\ \dfrac{(g_k + t_k^u) - z_k(x)}{t_k^u} & , \text{ if } g_k < z_k(x) \le g_k + t_k^u, \\ 0 & , \text{ if } z_k(x) > g_k + t_k^u. \end{cases} \quad (3)$$

$$k = 1 \text{ to } 2.$$

The highest value of a membership function is unity.

$$\mu(z_k(x)) + d_k^- - d_k^+ = 1$$

$$d_k^-, d_k^+ \ge 0, \; d_k^-.d_k^+ = 0, \; k = 1, 2. \quad (4)$$

for the membership objective goal of the'$\ge$ type and $\le$ type',

This transforms the goal program into fuzzy goal programming problem.

Where d_k^- are the amounts by which the energy and revenue objectives are underachieved and d_k^+ are the amounts by which the energy and revenue objectives are overachieved, of the kth membership goals. The deviational variables can either be zero or positive in the first condition and in the second condition, they cannot be basic variables simultaneously since they are dependent. From (1), the WMFGP model in (2) can be expressed as:

$$\textit{Find } X \text{ so as to Minimize } Z = \sum_{k=1}^{2} w_k d_k^-$$

subject to:

$$\frac{(g_k + t_k^u) - z_k(x)}{t_k^u} + d_k^- - d_k^+ = 1$$

$$\sum_{i=1}^{m} a_i x_i \le b_j, \; j = 1, 2, 3, ..., n \quad (5)$$

$$x_i, d_k^-, d_k^+ \ge 0; \; d_k^-.d_k^+ = 0; \; w_k = \frac{1}{t_k^u}; \; k = 1, 2; \; i = 1, 2, 3, ..., m.$$

Global Journal of Engineering Science and Research Management

The goal,

$$\frac{(g_k + t_k^u) - z_k(x)}{t_k^u} + d_k^- - d_k^+ = 1 \qquad (6)$$

can be transform into

$$z_k(x) = g_k + t_k^u d_k^- - t_k^u d_k^+ \qquad (7)$$

$$9773*x_1 + 13720*x_2 + 20381*x_3 + 7042*x_4 + 8085*x_5 + 15282*x_6 + 21495*x_7 + 4335*x_8 + 3937*x_9 + 16065*x_{10} + 10658*x_{11} + 9600*x_{12} + 7671*x_{13}$$

$$= 4990866553000 + 4000000000000*d_1 - 4000000000000*d_3 \qquad (8)$$

$$68480*x_1 + 108445*x_2 + 101863*x_3 + 39498*x_4 + 49849*x_5 + 112821*x_6 + 88157*x_7 + 21877*x_8 + 19449*x_9 + 96950*x_{10} + 68627*x_{11} + 60523*x_{12} + 37426*x_{13}$$

$$= 28690700489.15 + 28000000000*d_2 - 28000000000*d_4 \qquad (9)$$

Data

The data used in this study were collected from XYZ Distribution Company and PQR transmission station, for security purpose the identity of the Zone and Transmission station is left anonymous. Equations 8 and 9 are the form of equation 7 containing the objectives of energy transmitted and revenue generated. In the model, Power Holding Company of Nigeria (PHCN) PLC has approximately 4,990,866,553kwh of electricity for the period under review. This energy was transmitted to XYZ Distribution Company for utilization by thirteen (13) business units in the zone. Also a revenue generation of ₦28,690,700,489.15k by billing customer populations was made.

Results

TABLE 1: Results of energy in KWh

DISTRICTS	ENERGY /HR	ENERGY /MONTH
X1	13,825	9,954,000
X2	13,310	9,583,200
X3	17,154	12,350,880
X4	9,441	6,797,520
X5	10,414	7,498,080
X6	12,083	8,699,760
X7	20,383	14,675,760
X8	5,621	4,047,120
X9	3,800	2,736,000
X10	17,811	12,823,920
X11	12,259	8,826,480
X12	10,448	7,522,560
X13	8,883	6,395,760

These are energy values that satisfied the objectives of both energy and revenue for the thirteen districts

Global Journal of Engineering Science and Research Management

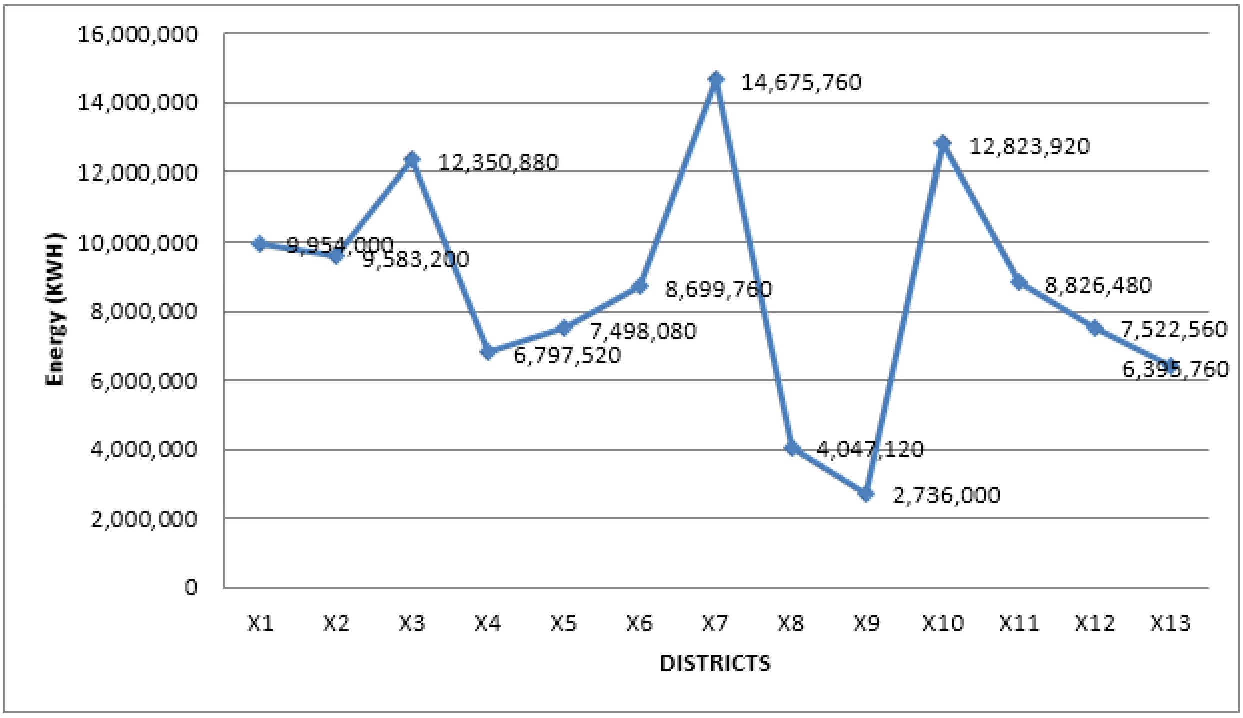
Discussion of results

From the results obtained; g_1 (amount of energy) 4,990,866,553kwh was overachieved (d_1^+) by 1.247200kwh of energy while g2(revenue generated) N28,690,700,489.15k, was overachieved (d_2^+) by ₦0.60k of revenue this implies that: g_1 will be achieved at 4,990,866,554.2472kwh and g2 at ₦28,690,700,489.75k.

The upper tolerance limits are: t_1^u (energy) 4,000,000,000kwh and t_2^u (revenue) ₦28, 000,000,000. This indicates that, these are the least values the objectives of energy and revenue can tolerate for the desired goals. These results are acceptable because the objective function minimized d_1^- *and* d_2^- *gave a value of* 0.0000 which is a global optimum solution; infeasibility zero and the over-deviational variables values from the targeted goals are acceptable.

Figure 1 is the values of Table 1 for the energy consumed in the various districts. The profile of energy consumption for the different periods per district seems to be maintained. The results obtained from the model application are very similar to those of the districts.

Figure 1: Monthly Energy consumption for 13 Districts of XYZ Electricity Distribution Zone.

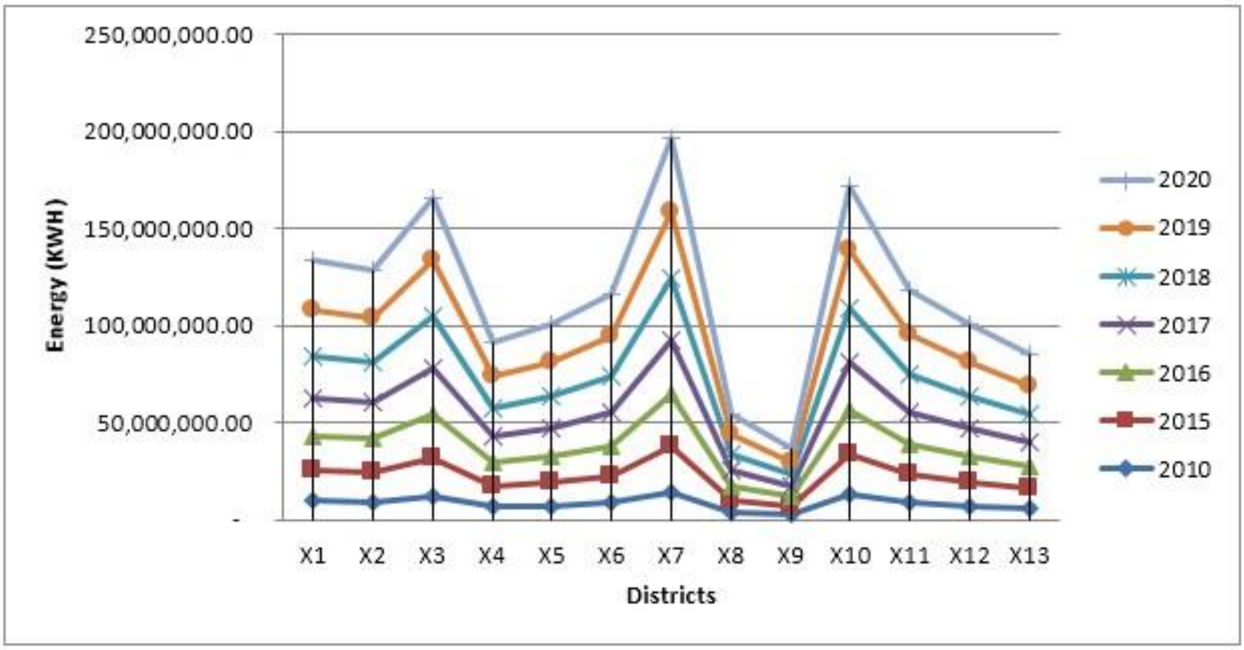


These are the values of energy in kilowatts hour for each district, with district x7 having the highest and district x9 with the lowest energy requirements

Figure 2 is the projection for energy to be consumed for the next six years based upon the Oshogbo Power control station of 10% projection rate for the energy consumed in the various districts. The profile of energy consumption for the different periods per district seems to be maintained.

Global Journal of Engineering Science and Research Management

Figure 2: Six years projection of Monthly Energy consumption for 13 Districts of XYZ Electricity Distribution Zone.



This is the profile for the projection of energy for XYZ Districts for the period of six years

Conclusion

This paper shows how weighted mini sum fuzzy goal programming (WMFGP) model can be used to develop more flexible and practical model for providing remedy to the electricity company energy allocation problems of Power Holding Company of Nigeria (PHCN) PLC. The negligible deviation of $2.50x10^{-8}$% for the energy goal of 4,990,866,553kwh and $2.09x10^{-9}$% for the revenue goal of ₦28, 690,700,489.15k shows a great potential in FGP modeling. The energy requirement of 290, 268, 416.20kwh in the next six years period will need increase in the generation capacity. These results further prove that FGP models have considerable promise in terms of control, flexibility and real world applicability. While XYZ Electricity Distribution Company has been selected for demonstrating the application of this model, the WMFGP model is flexible enough to be extended to handle larger sizes electricity allocation problems with little modification.

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Global Journal of Engineering Science and Research Management

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