Economic Load Dispatch of Egbin and Okpai Plants using PSO and GA: A Comparative Study with Quadratic Cost Function

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Abstract- In this research, the Hybrid Optimization Technique (HOT) is applied to solve the economic dispatch problem using the Egbin and Okpai power plants in Nigeria. Power flow analysis using Newton Raphson was carried out using the Power System Analysis Toolbox PSAT. The voltages and phase angles obtained from each simulation was used to compute the loss coefficient through the formation of B-Matrix. The B-Matrix developed, Generators Operating Limits (GOL), Quadratic Cost Function (QCF) of the generating units in addition with the HOT namely; Particle Swam Optimization (PSO) and Genetic Algorithm (GA) were used to set up the optimum dispatch problem programmed in the Matlab 2020b environment. Results for the Economic Dispatch ED for Egbin Plant shows an average transmission loss and fuel cost of 7.31MW and ₦35,104.18 were obtained using PSO while that of GA was 8.74MW and ₦161, 840 respectively. For Okpai Plant, an average transmission loss and fuel cost of 9.44 MW and ₦367, 394.92 was obtained using PSO while that of GA gave 11.74 MW and ₦49,101,333.33. The summarised results showed that Egbin Plant with its higher power rating has lowest loss transmission loss and fuel cost while Okpai Plant has the highest fuel cost. The summarized result is an indication that Egbin Plant is more efficiently operated at dispatch level when compared to other plants. Also, from the HOT, it was observed that the PSO out performed GA ED related problems.

Keywords: ELD, GA, Power Plant, PSO.

1. Introduction

Economic Load Dispatch (ELD) is an important operational components of the contemporary management of power snetworks. To satisfy the energy needs, the trend of network systems is expanding quite rapidly [1]. Operating the plant unit as inexpensively as possible becomes critical as the grid system develops. The unit commitment and the online economic dispatch OED are the two distinct processes in the economic generation scheduling problem. The unit commitment entails choosing a unit that will deliver the specified operating reserve limit and the expected system load for the needed amount of time at the lowest possible cost. In order to reduce the overall cost of fuel, the OED distributes loads to generating plants that are connected to the network.

Demand for electricity in Nigeria is far beyond the power generated by the available generating power stations and this situation is serving as an obstacle to the national development of the country [2]. Countries whose power supply are epileptic in nature, delays its development and stand a chance of losing a lot of potential investors. For a profitable operation of power utilities in Nigeria, a reliable power supply is critical and this can only be achieved when the generating units of the power plants are properly scheduled to meet up with the load demand. For an economic operation of the Nigerian power generating stations, the generating units efficiency, transmission loses and cost of operation are vital factors to be considered. For years, Nigerian power generating stations have faced challenges in power generation due to increased load demand [16]. This is largely a result of units experiencing emergency or forced outages, leading to partial or total system collapse. These challenges arise from pushing available units beyond their normal operating conditions, resulting in power stations generating power at a loss and a corresponding poor network reliability [3]. This study aims to present the PSO optimization method to address complex optimization problems in Egbin and Okpai power plants. These problems are nonlinear, non-differentiable, and multi-modal. The Egbin and Okpai power plants were chosen for this analysis because of their importance in the Nigerian power sector. Egbin is often used as a reference bus for most power system analysis. The choice of PSO parameters would have significant effects on optimization performance as well as the problem's computational behavior and effectiveness. Finally, the project will create MATLAB programs that employ the PSO approach to address the ELD problem. Because it offers a high-level programming language and development tools which allows you create and analyze algorithms and applications fast, MATLAB was selected for this analysis. Programming and developing algorithms with the MATLAB language can be done more quickly than with traditional languages since low-level administrative duties like allocating memory, defining data types, and declaring variables are no longer required. Also, PSO was selected for this research due to its fast speed of convergence. In addition, PSO algorithm can be realized by simply using few numbers of parameters that need just little adjustments. The choice of PSO technique shall be validated by using genetic algorithm (GA).

A novel PSO-based method for resolving a power system's ED problem was reportedly introduced in [2]. Four distinct case studies, ranging from 3 to 40 generation units, were utilized to test the solution process. The suggested approach was able to pinpoint the precise power output of each generator unit by addressing the constraint ED problem. The suggested algorithm does this by minimizing the generation units' total cost function. The outcomes were contrasted with the findings of earlier PSO and GA approaches that had been used. The outcomes showed that the suggested method could solve the ELD problem with a superior degree of quality thanks to its fast convergence, resilience, and mathematical simplicity. In a comparative analysis by [4], the QP and the General Algebraic Modeling System (GAMS) was employed to address ELD problems. The best solution to the power dispatch problem was found by carefully examining various equality and inequality requirements using the suggested methodology. Simulations covering four distinct scenarios were conducted to confirm the algorithm's efficacy. The outcomes derived from the suggested technique were contrasted with those from other pertinent, currently-available methods found in literature. The method's superiority over other strategies is supported by the experimental results, particularly with regard to its optimal search behavior and robustness. The analysis was not conducted on various power generating plants to see how effectively they performed.Author [5] presented a multi-agent system of decentralised architecture for ED of distributed generators (DGs) on micro grids. All the DGs have similar agents that can detect localised information or vital information from the neighbouring DGs. While comparing themselves, agents tend to maximize their gains, which allow them to attain an optimal global solution. The paper presented vital situations for minimal operational cost of micro grids. System simulation was not performed in a large interconnected power generating station, rather it was done on a micro grid.

According to [6], a hybrid approach based on PSO and GSA was presented as a unique heuristic optimization strategy to address difficult ELD problems. The social thinking function of PSO and the local search capabilities of GSA are combined in this algorithm, which is known as hybrid PSOGSA. In order to evaluate the PSOGSA algorithm's performance, four distinct standard test cases with varying dimensions and levels of complexity that resulted from real-world operating restrictions were used. The outcomes were contrasted with newly published techniques. The comparison with other methods in use validated the algorithm's efficiency and resilience.

To address the traditional Economic Dispatch (ED) problem, the author [7] presented a research that prohibits a unit from operating in the forbidden zones, a heuristic algorithm was created to modify the generation output of the unit. Several test systems had been used to evaluate the solution algorithms. The outcomes were contrasted with those of traditional techniques. In Real Coded GA, the algorithm's accuracy was increased while its execution time was decreased by coding the generator outputs. In doing so, it managed to both preserve the benefits of GA over conventional ED techniques and get rid of its primary drawback—long execution times. Directional Search GAs can provide solutions with few iterations, minimal execution time, and a smaller population size. Challenges associated with GAs include prolonged computational time, slow convergence speed towards the global optimum solution, non-convergence to the global solution, and potential trapping into local optima. Author [8] presented a different method to tackle the practical ED problems. A trial was carried out to know the lowest amount engaging PSO algorithm, while applying the three generating plants data. In the study, parameters like loss coefficients, max-min power limit and cost function were utilised. In order to get the lowest cost for various power demand, PSO and SA were engaged. Comparison with the conventional method gives PSO a good outcome plus nice convergence characteristics. The usefulness and possibility of the proposed technique were shown using three generating plants for a case study. The research shows promising outcomes, indicating that the proposed method of computation has the ability of effectively finding top quality solutions tackling economic dispatch problems. The author [9] presented a short-term economic load dispatch employing Differential Evolution (DE) technique. The analysis was applied to four Nigerian thermal power plants (i.e. Egbin, Sapele, Delta and Afam) for a period of one week using MATLAB software. For day 1, an average power contribution of 885.2MW, 373MW, 89.2MW and 370.9MW were obtained by the respective plants. The results obtained revealed the possibility of applying the technique for a longer duration in solving ELD problem of larger thermal plants. The analysis was only applied to thermal power stations and was not validated using other optimization technique. Author [10] presented a combine Economic and Emission power dispatch optimization, which was resolved by DE method applying MATLAB software design method. Two cases were considered, the first was based on a system that has no transmission losses, with and without penalty factor and the second was based on a system with transmission power losses, with and without penalty factor. The outcomes of the two different case shows a decrease in overall production cost and rate of emission while regulating the output of each generating plant tied to the parallel network. According to the author [11], they used ELD using lambda iterative technique. The analysis was performed on both the old and expanded Nigerian grid using MATLAB software. The old grid consists of four thermal plants (i.e.Egbin, Sapele, Ugheli and Afam) while the expanded National grid has seven thermal plants (i.e. Egbin, Sapele, Ugheli, Afam, Olorunsogo, Geregu and Omotoso. After the analysis, conclusion was drawn that, generation cost of most of the plants operated around their maximum limit increased exponentially. Also it was observed that, the system do experience lower losses when operated nearer to the load centre. This author [12] presented Particle Swarm Optimization (PSO) based ELD applied on the Nigerian 330kV, 31-bus network. In this study Convex-type ELD was looked into; the thermal plant fuel cost was modelled using quadratic polynomial function. PSO was used to obtain the optimal power output of each plant. PSO results were compared to that of Genetic Algorithm (GA) and Differential Evolution (DE) with respect to total power loss and generation cost. The least power loss and cost of generation was that obtained by PSO compared to GA and DE. Also, DE gave a quite impressive performance. According to [13] presented an evaluation of economic load dispatch issue of power generating plants. Ant Colony Search Algorithm (ACSA) method was introduced for tackling the economic load dispatch issue. ACSA is a meta-heuristic method designed to analyze challenging problems in combinatorial optimization. The suggested approach was evaluated using the six-unit generating units of the Egbin Thermal Power Plant in Nigeria as a case study. The program was constructed in MATLAB code for this presentation. The Lambda approach was compared with the results obtained through the use of ACSA. The final outcome demonstrates that the suggested algorithm has the benefit of finding an optimal solution to address the problems with power loss and operational costs. In [14], a technique based on Particle Swarm Optimization (PSO) with a modified evaluation function, accounting for wind power penetration, was proposed to tackle the Economic Load Dispatch (ELD) problem. The average hourly wind speed was computed utilizing data from a wind farm situated in Zafarana, Egypt. The analysis was conducted both with and without wind power generation to illustrate its impact on the overall system cost. The implementation was achieved through MATLAB platform. The study was performed on three thermal units with different load demands with and without losses. Performing the analysis and neglecting losses and considering a load demand of 585MW and 800MW, a minimum cost of 5821.4R/hr and 7738.5R/hr were obtained respectively. For a load demand on 585.33MW and 812.57MW and considering losses, minimum cost of 5894.2R/h and 7992.1R/h were obtained respectively. A power loss of 7.162MW and 13.97MW were also obtained respectively. Incorporation of the wind farm impacted tremendously on the system. According to the paper [15] presented an overview of energy generation at the Jebba hydroelectric power station. Hydrological data (daily inflow and outflow rate) and generated energy was collated between the period of 2009-2016 from both Jebba hydroelectric power station and National Control Centre (NCC), Osogbo. The data collated was analyzed using Time Series and Correlation employing Microsoft Excel platform. A further analysis was performed by comparing the conversion efficiency of the energy contained in flowing water to the actual generated energy. A conversion efficiency of 0.7059 was obtained which satisfies the linear relationship between the two quantities. MATLAB software was not employed in analysing the system.

The increasing complexity and operational constraints in modern power systems necessitate more effective and efficient solutions to the Economic Load Dispatch (ELD) problem. Traditional methods often fall short in dealing with non-linearities, multiple objectives, and system uncertainties such as power losses, emission constraints, and renewable energy integration. In recent years, a variety of heuristic and metaheuristic algorithms, including Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Differential Evolution (DE), and others, have been proposed to enhance the solution quality and computation efficiency of ELD problems. While these techniques have shown promise in certain scenarios, there is still a need for robust and scalable methods that can provide optimal or near-optimal solutions across a wide range of system configurations, including large-scale power networks, microgrids, and systems with renewable integration. The motivation for this study stems from the growing demand for more adaptive, cost-effective, and reliable ELD strategies that can accommodate the dynamic nature of power systems network like Egbin, and Okpai power plants in Nigeria while minimizing cost and losses.

2. Methodology

This research employs a structured and systematic approach to perform Load Flow Analysis and Economic Load Dispatch (ELD) for selected Nigerian thermal and gas power plants using MATLAB and Power System Analysis Toolbox (PSAT). The methodology is divided into the following key stages:

2.1. Data Collection and Input Parameters

The analysis is based on comprehensive data obtained from two major power plants in Nigeria—Egbin Thermal Power Plant and Okpai Gas Power Plant. The following input parameters were collated and used in the study:
Single Line Diagrams: Representing the network structure of the Egbin and Okpai power stations.
Line Data: Including transmission line parameters such as resistance, reactance, and line charging susceptance.
Bus Data: Including voltage magnitudes, angles, generation, and load data for each bus in the network.
Cost Coefficients: Representing the fuel cost characteristics of the generators at Egbin and Okpai.
Generator Limits: Minimum and maximum power output constraints for each generating unit.

2.2. Load Flow Analysis

Load flow analysis was carried out using PSAT in MATLAB to determine the steady-state operating conditions of the power system network. This involved computing:

- Real and reactive power flows across the network,
- Voltage profiles at each bus,
- System losses.

The results of the load flow analysis serve as the input baseline for the economic load dispatch simulation.

2.3. Economic Load Dispatch Implementation

An Economic Load Dispatch algorithm was implemented in MATLAB using the collated generator data. The objective function minimized was the total generation cost subject to power balance and generator capacity constraints. The following steps were performed:

1. Formulation of the ELD problem using cost coefficients.
2. Application of optimization techniques (e.g., PSO, hybrid methods if applicable).
3. Evaluation of generator outputs that minimize fuel cost while satisfying system demand.

2.4. System Evaluation

The ELD results were compared for different scenarios to evaluate:

- Total generation cost,
- Power allocation across generating units,
- Impact of generator constraints and network configuration.

2.5. Tools and Software

The following tools and software were used for modeling, simulation, and analysis:

MATLAB (Version 2020b): Used for implementing economic load dispatch algorithms and processing data.
PSAT (Version 2.1.11): Utilized for conducting load flow analysis within the MATLAB environment.

2.6. Formation of Y Bus

$$Y_{ii} = B_{ij} + \sum_{i=1, i\neq j}^{n} y_{ij} \qquad (1)$$

Where,
y_{ij} is the series admittance in Siemens.
B_{ij} is the half line shunt admittance in Siemens.
The off diagonal elements Y_{ij} of the bus admittance matrix is equal to the negative of the admittance value of the connecting element between buses i and j, if any.

$$Y_{ij} = Y_{ji} = -y_{ij} = -\frac{1}{z_{ij}} \qquad (2)$$

The flow chart for this process is presented in Figure 1 while Figure depicts the flow chart for the Load Flow Process LFP.

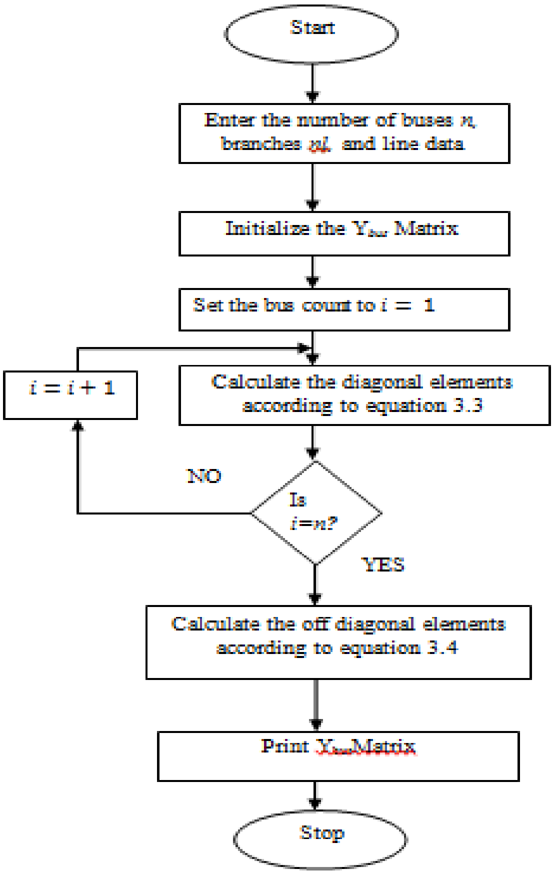

Figure 1: Flow Chart of Bus Admittance Matrix

2.7. Formation of Loss Coefficient Matrix (B-Matrix)

The B-matrix of per unit loss coefficients is obtained by extracting the real part of the respective elements of H according to the equation:

$$H = K \times C^T \times R_{bus} \times conj(C) \times conj(K) \quad (3)$$

where H is the hermitian matrix equal to the complex conjugate of its own transpose.

$$K = \begin{bmatrix} a_i & 0 & 0 & 0 \\ 0 & \ddots & 0 & 0 \\ 0 & 0 & a_n & 0 \\ 0 & 0 & 0 & I_n^o \end{bmatrix} \quad (4)$$

where

$$a_i = \frac{1-jS_i}{conj(V_i)} \quad (5)$$

$$I_i = a_i P_{gi} \quad (6)$$

$$I_n^o = -\frac{V_1}{Z_{11}} \quad (7)$$

$$S_i = \frac{Q_{gi}}{P_{gi}} \quad (8)$$

a_i is the complex quantity on the principal diagonal.
I_i is the output current from the generator.

S_i is the complex power of the generating units. The reactive power Q_{gi} is assumed to be constant fraction S_i of the real power P_{gi}, over a period of interest at the generator bus.
I_n^o is the no load current.
C is the current transformation matrix, C^T denotes its transpose.

$$C = \begin{bmatrix} 100 \\ d_i t_i \dots d_i t_n \\ \vdots \\ d_n t_i \dots d_n t_n \end{bmatrix} \quad (9)$$

$$d_i = \frac{IL_i}{I_D} \quad (10)$$

d_i is the constant fraction of the total load
IL_i is the load injection current given as

$$IL_i = \frac{P_i - jQ_i}{V_i^*} \quad (11)$$

I_D is the composite system load, which is the algebraic sum of the load currents injected into the network at the buses, expressedas

$$I_D = \sum_{i=2}^{n} IL_i \quad (12)$$

n is the number of load buses
The quantity t_i is computed from d_i and the row one element of Z_{bus}, expressed as

$$t_i = \frac{Z_{11}}{W} \quad (13)$$

$$W = \sum_{i=2}^{n} d_i Z_{1i} \quad (14)$$

R_{bus} is the symmetrical real part of Z_{bus}

2.8. PSO Problem Formulation

PSO can be conceptualized as both a single-objective and multi-objective problem, characterized by non-linearity, lack of smoothness, and non-convexity. The single-objective problem can be expressed as Economic Load Dispatch (ELD) considering transmission line losses. By combining the objective and constraints, the problem can be mathematically defined as a nonlinear constrained single-objective optimization issue, represented by equation (15).

Minimize: [F_T (P), P_L(P)]
Subject to: g (P) = 0 (15)
h (P) ≤ 0

where g = equality constraint h = inequality constraint , F_T = total generation cost or fuel cost and P_L is the total power loss or transmission loss in the system.

2.9. Objective Function

Resolving the ELD problem requires adherence to the constraints imposed by the generation units while simultaneously optimizing the generation process according to the cost factors associated with each unit. The total operational cost of the network is determined by the sum of the fuel cost functions of all generation units in the power system, expressed in equation (16).

$$\text{Minimize} F_T = \sum_{i=1}^{n} F_i(P_i) \quad (16)$$

The cost function outlined in equation (16) can be represented as an approximation of a quadratic function relating to power generation, elucidated in equations (17) and (18) correspondingly.

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \quad (17)$$

$$F_T = \sum_{i=1}^{n} a_i + b_i P_i + c_i P_i^2 \quad (18)$$

where $F_i(P_i)$ is the fuel cost function of the generating units in (₦/h). a_i, b_i and c_i are the fuel cost coefficient of the i-th generator and P_i is the generated real power output by the i-th generator (MW). F_T is the total fuel cost and n is the number of generators including the slack bus.

2.10. Equality Constraint

In the first case, balance is met when the sum of generation equals the sum of load, considering the equation as loss-less as shown in equation (19).

$$\sum_{i=1}^{n} P_i = P_D \quad (19)$$

In the second scenario, equilibrium is achieved when the total generated power matches the combined values of system load and total transmission power losses. Typically, within a power system, the generated power must adequately cover the load demand along with the losses occurring during power transmission. Given that transmission lines are positioned between the generating units and loads, P_{loss} can manifest at any point before the power reaches the load (P_D). Any insufficiency in generated power results in an inadequate supply to meet the load demand, potentially leading to issues for both the system and the loads. Any shortfall in power generation will result in a shortage of energy to feed load demand, which could lead to challenges with the system and loads.

$$\sum_{i=1}^{n} P_i = P_D + P_{loss} \tag{20}$$

where P_D is the system load demand and P_{loss} is the transmission line loss.
Utilizing the B-matrix provides a solution for the generated powers of various units as variables. Equation (21) illustrates the function for computing P_{loss} through the application of the B-matrix method.

$$P_{loss} = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j \tag{21}$$

Where P_{loss} is the total transmission loss in the system also known as Kron's loss formula.
P_i, P_j is the generated power by the i-th and j-th generating units respectively and
B_{ij} is the element of the B-matrix between i-th and j-th generating units.

2.11. Inequality Constraints

When a generator's power output falls below a certain threshold for optimal system operation, the unit is not placed on the bus bar since it is unable to produce electricity at that low level. Therefore, there are lower and upper operational limits for the output power of each power generating unit, and the unit power falls between these limits. Equation (22) can be used to construct this as an inequality constraint.

$$P_i^{min} \leq P_i \leq P_i^{max} \tag{22}$$

Where $P_i^{min} and P_i^{max}$ is the minimum and maximum power output limit of the i-th generator.

The rotor's overheating limits the highest reactive power, and the machine's stability limit limits the minimum reactive power. As a result, for the generator to operate steadily, its reactive powers Q must fall within the range given by the inequality as indicated by equation (23).

$$Q_i^{min} \leq Q_i \leq Q_i^{max} \tag{23}$$

There should be some variation in the phase angles δ and voltage magnitudes at different bus bars. For reasons of transient stability, the transmission's usual working angle should be between 30 and 45 degrees. A higher operating angle ensures optimal use of the available transmission capacity by lowering the lower limit of delta δ and reducing stability during faults.

2.12 Running space capacity constraints

These constraints are essential to meet:

i. Forced outages of one or more alternators on the system, and
ii. Unanticipated fluctuations on the system load.

In addition to satisfying load demand and different transmission line losses, the overall generation should be such that there is a minimum amount of spare capacity available.

Transmission line constraints

The transmission line circuit's capacity to carry active and reactive power is constrained by its thermal capability, as indicated by:

$$C_p \leq C_{pmax} \tag{24}$$

Where C_{pmax} is the maximum loading capacity of the P^{th} line.

Network security constraints

When a system is originally operating smoothly and there is an unplanned or forced outage, it is normal for some of its constraints to be violated. As the analysis encompasses a large system, the complexity of these constraints intensifies, considering the increasing number of constraints.

Parameters selection in PSO

i. Velocity Updating

$$V_i^{(t+1)} = V_i^t + C_1 R_1 (X_{Pbesti} - X_i^t) + C_2 R_2 (X_{Gbesti} - X_i^t) \tag{25}$$

wherei = 1……n,
n - Population size
C_1- Cognitive acceleration constant
C_2- Social acceleration constant
R_1, R_2- Uniform random value in large (0-1)
V_i^t- Velocity of particle 'i' at iteration't'
V_i^{t+1} - Modified velocity of particle 'i' at iteration t+1

ii. Position Modifications

$$X_i^{t+1} = X_i^t + \Delta t \times V_i^{(t+1)} \tag{26}$$

X_i^{t+1} - modified position of particle 'i' at iteration (t+1)

Δt – change in time, measured in iteration step and time increment of iteration is 1.

iii. Acceleration Constant

Acceleration coefficients represent the weighting of the stochastic acceleration terms that pull particles towards Pbest and Gbest. Particles tend to move abruptly and there is a greater chance of being trapped in false optima if these constants have an excessively high value. **Inertia weight**

PSO depends greatly on inertia weight since it controls particle speed. Therefore, it's crucial to choose it wisely. The most appropriate way to set inertia weight, which is typically employed in PSO applications, is to linearly decrease it from a relatively high value to a relatively low value over the course of the run period, taking into mind both simplicity and efficiency. The commonly accepted literature values for ω_{max} = 0.9 and ω_{min} = 0.4, respectively. In the ongoing study, the inertia weight linearly decreases from 0.9 to 0.4 during runtime, following the general practice outlined in equation (3.51).

$$\omega = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{iteration_{max}} \times iteration_k \quad (27)$$

Where,

ω_{max}: Final inertia weight;

ω_{min} : Initial inertia weight;

$iteration_{max}$: The maximum number of iterations which is arbitrarily set;

$iteration_k$: The k^{th} iteration which is considered as the current iteration.

iv. Swarm Size

Swarm size bears an impact on PSO performance. The algorithm becomes stuck in local optima when there are insufficient particles, and it runs slowly when there are excessively many particles. The convergence rate is impacted by the choice of swarm size, yet there isn't a precise, widely accepted rule in the literature about this. However, typically, the swarm size should grow in tandem with the problem's increasing dimension. It is a phenomenon that depends on the particular situation and changes with each problem.

iv. Initialization Technique

The random initialization of particles can aid the PSO algorithm in efficiently exploring the search space across different regions, identifying solutions of higher quality, and improving the computational performance of PSO.

Number of Particles

The choice of the number of particles is contingent on the nature of the problem. It begins with a small number of particles and is incrementally increased, determining the optimal number of particles. Generally, the number of particles falls within the range of 20 to 40. In many cases, 15 particles suffice to achieve favorable outcomes. However, for challenging or exceptional problems, a range of 100 to 200 particles may be selected

Dimension of Particles

$$D = n_p \times n_g \quad (28)$$

where

n_p– number of particles and

n_g – number of generation

Maximum Velocity

The greatest change a particle can undergo in a single iteration is designated as V^{max}.

PSO performance is also impacted by the value of maximum velocity. A value that is too high causes the particles to travel erratically and attract the global best (Gbest) function quickly without sufficiently exploring the search space. They might so overshoot the search space, and there's a greater chance of being caught in a false optima. If it is too tiny, on the other hand, the movement of the particles becomes excessively limited, increasing the computational overhead and possibly preventing the algorithm from convergeing.

Stopping Criteria

The stopping conditions for PSO involve achieving the maximum specified number of iterations or meeting a minimum error requirement. When the iteration count reaches the predefined maximum in PSO, the most recent iteration represents the optimal generation power unit with the minimum total generation cost at the peak evaluation function iteration. The choice of stopping criteria is contingent on the decision-maker and the specific problem at hand. It could involve a pre-determined number of iterations, reaching a specified solution quality, exceeding a designated time limit, observing no change in successive iterations, or a combination of these factors.

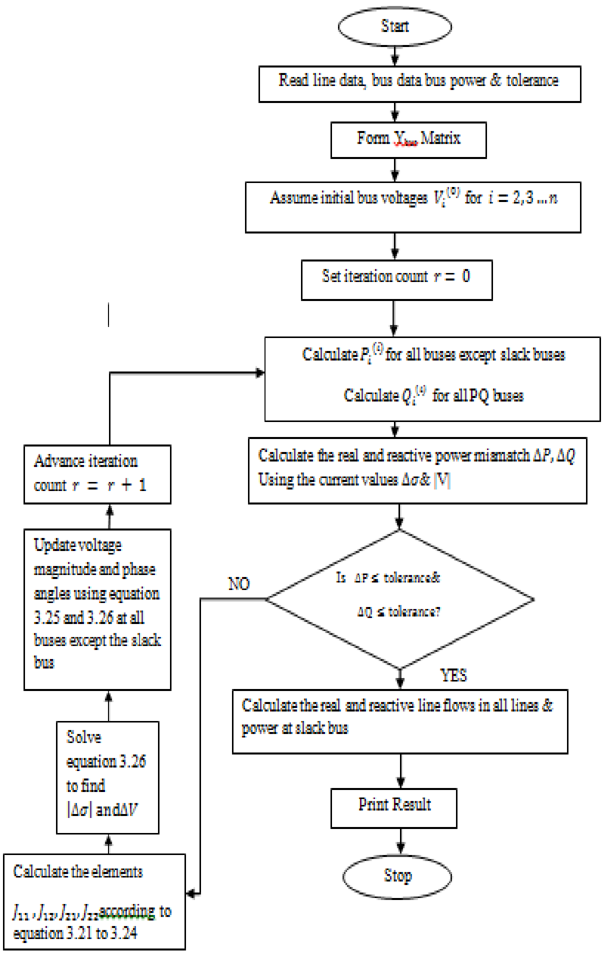

Figure 2: Flow Chart of Newton Raphson

generation cost at the maximum evaluation function iteration.

Selection of stopping criteria depends on the decision-maker and problem in hand. The stopping conditions for the PSO process can be a pre-specified number of iterations, achievement of a specified solution quality, expiration of a designated time, absence of change in successive iterations, or a combination thereof. The PSO process is detailed as follows:

STEP 1: Initiate PSO Parameters: Define key PSO constants, such as C_1, C_2,n_g, inertia weight, and establish limits for the generation power of each unit. Specify parameters including maximum iterations, acceptable error, lambda, power demand, loss coefficient matrix, and the fuel cost coefficient for individual units.

STEP 2: Randomize Population Initialization: Randomly set the initial individuals in the population for all units, adhering to the specified limits for each unit. This involves determining individual dimensions, search points, and velocities.

STEP 3: Evaluate Particle Fitness:

$$F = F_T + \lambda \times E \qquad (29)$$

where F is the particle's fitness function, λ is lambda assumed to be 100 and E is the particle's error.

$$E = \left|\sum_{i=1}^{n} P_i - P_D - P_{loss}\right| \qquad (30)$$

STEP 4: Assume a global best minimum cost such that, Gbest = 1.

STEP 5: Update Personal Best (Pbest): Utilize the Pi obtained thus far as the Pbest for each particle, with associated costs being considered as Pbest cost..

STEP 6: Record Global Best (Gbest): Record and store the global best along with its corresponding real power generation.

STEP 7: Set Iteration Count: Establish the iteration count for tracking progress.

STEP 8: Compute Inertia Weight: Calculate the inertia weight according to the defined equation.

STEP 9: Update Particle Velocity: Adjust the particle velocities, ensuring they remain within the specified range. If a velocity falls outside this range, clamp the velocity for each particle.

$$\text{If} V_i^{(t+1)} > V^{max}, then V_i^{(t+1)} = V^{max} \qquad (31)$$

$$V_i^{(t+1)} < V^{min}, then V_i^{(t+1)} = V^{min} \qquad (32)$$

STEP 10: Particle's new position is modified using

$$X_i^{t+1} = X_i^t + \Delta t \times V_i^{(t+1)}. \qquad (33)$$

STEP 11: Evaluate New Position Fitness: Evaluate the fitness of each particle's new position.

STEP 12: Update Personal Best (Pbest) Values: For each individual particle, compare its fitness value with Pbest. If the current fitness value surpasses Pbest, update Pbest values and positions accordingly.

STEP 13: Compare with Global Best Gbest: Compare the best current fitness evaluation with the population Gbest. If the current value proves superior to Gbest, reset Gbest to the current best position and update the fitness value.

STEP 14: Repeat steps 3 to 9 until the established stopping criterion, based on a maximum iteration, is met.

3. Results and Discussion

The results obtained after the various analyses were performed are presented below. The results comprise of the load flow analysis and economic load dispatch of Egbin and

Okpai power stations. The power flow and line flow of Egbin power plant are indicated in Tables 1 and 2 respectively.

Table 1: Power Flow of Egbin Power Plant

Bus No.	V(pu)	Angle	Pgen	Qgen	Pload	Qload
	(pu)	(Deg)	pu	Pu	Pu	pu
1	1.0000	0.0000	6.6500	0.8383	0.0000	0.0000
2	0.9909	-1.6304	0.0000	0.0000	1.8600	0.4300
3	0.9945	-1.6448	0.0000	0.0000	1.5200	0.2100
4	0.9711	-7.0523	0.0000	0.0000	1.8100	0.4900
5	0.9945	-0.6260	0.0000	0.0000	1.4200	0.7400

Table 2: Line Flow of Egbin Power Plant

From Bus	To Bus	Pflow	Qflow	From Bus	To Bus	Pflow	Qflow	Ploss	Qloss
		Pu	pu			pu	Pu	pu	pu
1	2	1.8673	0.2567	2	1	-1.8600	-0.4300	0.0073	-0.1733
1	3	1.5252	0.0197	3	1	-1.5200	-0.2100	0.0052	-0.1903
1	4	1.8372	-0.0839	4	1	-1.8100	-0.4900	0.0272	-0.5739
1	5	1.4203	0.6458	5	1	-1.4200	-0.7400	0.0003	-0.0942

3.1. *Load Flow of Egbin Power Plant*

Table 1 shows that all the buses are operating within the acceptable limit of 0.95pu to 1.05pu. The voltage profiles of the load buses (i.e bus 2, bus 3, bus 4 and bus 5) are 0.9909pu, 0.9945pu, 0.9711pu and 0.9945pu respectively. The line flow results for the power plant network are presented in **Table 2**. The analysis reveals a real power loss of **39.95 MW** and a reactive power loss of **-103.17 Mvar** within the network. Additionally, the power flow and line flow data specific to the Okpai Power Plant are detailed in **Tables 3** and **4**, respectively.

Table 3: Power Flow of Okpai Power Plant

Bus No.	V(pu)	Angle	Pgen	Qgen	Pload	Qload
	(pu)	(Deg)	Pu	Pu	Pu	pu
1	1.0000	0.0000	3.3141	2.0631	0.0000	0.0000
2	0.9109	-1.4352	0.0000	0.0000	1.1032	1.0113
3	0.8233	-2.6530	0.0000	0.0000	0.9388	0.9013
4	0.8889	-1.7806	0.0000	0.0000	0.6566	0.5691
5	0.9039	-1.6294	0.0000	0.0000	0.2716	0.2263

Table 4: Line Flow of Okpai Power Plant

From Bus	To Bus	Pflow	Qflow	From Bus	To Bus	Pflow	Qflow	Ploss	Qloss
		Pu	Pu			pu	pu	pu	pu
1	2	3.3141	2.0631	2	1	-3.0679	-2.0267	0.2463	0.0364
2	3	1.0214	0.6076	3	2	-0.9388	-0.9013	0.0826	-0.2937
2	4	0.6699	0.3913	4	2	-0.6566	-0.5691	0.0133	-0.1778
2	5	0.2733	0.0166	5	2	-0.2716	-0.2263	0.0017	-0.2098

3.2. *Load Flow of Okpai Power Plant*

Table shows that all the buses are operating outside the acceptable limit of 0.95pu to 1.05pu. The voltage profiles of the load buses (i.e bus 2, bus 3, bus 4 and bus 5) are 0.9109pu, 0.8233pu, 0.8889pu and 0.9039pu respectively. The line flow results of the power plant network are presented in Table 4. The analysis indicates a real power loss of 34.384 MW and a reactive power loss of -64.486 Mvar within the system. The loss coefficient matrix (B-Matrix) for the Egbin Power Plant is shown below.

$$
B=\begin{pmatrix}
0.8497 & 0.1103 & -0.1195 & -0.1256 & -0.1177 & 0.1032 \\
0.0968 & 0.1154 & -0.1218 & -0.1281 & -0.1204 & 0.1103 \\
0.0878 & -0.1118 & 0.1199 & 0.1261 & 0.1183 & -0.1054 \\
-0.0937 & -0.1183 & 0.1267 & 0.1332 & 0.1250 & -0.1118 \\
-0.0888 & -0.1119 & 0.1197 & 0.1259 & 0.1182 & -0.1058 \\
0.1032 & 0.1177 & -0.1228 & -0.1292 & -0.1216 & 0.1136
\end{pmatrix}
$$

Table 5: Best power output generation and transmission losses of Egbin power plant at different load demands using PSO

Power Designation	Load Condition		
	594.9	**661**	**727.1**
P1 (MW)	86.5766	95.1900	103.5960
P2 (MW)	104.7782	116.9300	129.1873
P3 (MW)	101.7185	113.2400	124.8085
P4 (MW)	101.6704	113.1600	124.6766
P5 (MW)	101.7673	113.2900	124.8840
P6 (MW)	104.5254	116.6300	128.7852
Total power output	**601.0364**	**668.4400**	**735.9376**
Total generation cost(₦/hr)	**31902.3564**	**35456.2200**	**39302.5526**
Transmission loss	**6.1364**	**7.4400**	**8.8376**

Table 6: Best power output generation and transmission losses of Egbin power plant at different load demands using GA

Power Designation	Load Condition		
	594.9	**661**	**727.1**
P1 (MW)	91.3800	98.9600	105.9300
P2(MW)	109.3700	129.5200	119.4700
P3(MW)	105.8800	96.6200	114.7700
P4(MW)	75.4500	110.6800	142.1700
P5(MW)	58.5500	124.1500	134.0900
P6(MW)	161.5400	110.0300	120.8300
Total power output	**602.1700**	**669.9600**	**737.2600**
Total generation cost(₦/hr)	**144620000.0000**	**160500000.0000**	**180460000.0000**
Transmission loss	**7.2700**	**8.9600**	**10.1600**

Table 7: Best power output generation and transmission losses of Okpai Power Plant at different load demands using PSO

Power Designation	Load Condition		
	315	**350**	**385**
P1 (MW)	110.6400	121.3800	132.89
P2(MW)	108.1600	120.2500	134.9900
P3(MW)	104.3700	117.9900	127.9500
Total power output	**323.17**	**359.62**	**395.83**
Total generation cost(₦/hr)	**83551.8300**	**85221.5700**	**88151.6200**
Transmission loss	**8.1700**	**9.6200**	**10.8300**

Table 8: Best power output generation and transmission losses of Okpai Power Plant at different load demands using GA

Power Designation	Load Condition		
	315	**350**	**385**
P1 (MW)	112.3500	122.95	137.99
P2(MW)	113.95	125.12	139.91
P3(MW)	100.33	114.08	121.04
Total power output	**326.63**	**362.15**	**398.94**

Table 9: Summary of Egbin Power Plant Result

Load Condition	Optimization Technique				Initial Losses at all Loading Conditions	
	PSO		GA		MW	MVAR
	Losses (MW)	Cost (N/hr)	Losses (MW)	Cost (N/hr)	34.384	64.386
594.9	6.14	31902.36	7.27	144620000		
661	7.44	35456.22	8.96	160500000		
727.1	8.84	39302.55	10.16	180460000		
Total Losses	**22.42**		**26.39**			

Table 10: Summary of Okpai Power Plant Result

Load Condition	Optimized Losses				Initial Losses at all Loading Conditions	
	PSO		GA		MW	MVAR
	Losses (MW)	Cost (N/hr)	Losses (MW)	Cost (N/hr)	39.95	103.17
315	8.17	83551.83	11.63	46554000		
350	9.62	85221.57	12.15	48996000		
385	10.83	88151.62	13.94	53254000		
Total Losses	**28.62**		**37.72**			

3.3. Egbin Power Plant using PSO and GA

The loss coefficient matrix of Egbin power plant otherwise known as the B-matrix coefficient was developed together with generating power limits and the fuel cost function used to set up the PSO analysis in MATLAB code. Egbin B-matrix is a 6x6 which is required to compute the losses in the transmission line for more reasonable and accurate result.

Tables 5 and Table 6 contains the optimal power dispatch of Egbin thermal power plant employing PSO and GA techniques respectively. The simulation was performed at different load conditions of 594.9 MW, 661 MW and 727.1 MW. These load conditions were chosen based on 90%, 100% and 110% loading corresponding to under-loading, normal loading and slightly over-loading conditions respectively. In each load condition, the optimal power dispatch of each unit, the cost of generation and the transmission losses were obtained.

For the PSO based optimal power dispatch, the transmission losses of 6.14 MW, 7.44 MW and 8.84 MW were obtained at the respective load conditions while total generation costs of N31902.35, N35456.22 and N39302.55 were respectively obtained. Also, Figure 3 through Figure 5 depicts the convergence graph which is the plot of fitness function against the number of iterations. This graph represents the rate at which the particles searches for an optimal point.For the GA based optimal power dispatch, the transmission losses of 7.27MW, 8.96MW and 10.16MW were obtained at the respective load conditions while total generation costs of N144620000, N160500000 and N180460000 were respectively obtained. Also, Figure 6 through Figure 8 depicts the convergence graph which is the plot of fitness function against the number of iterations. The Loss coefficient matrix (B-Matrix) of Okpai

$$B = \begin{pmatrix} 0.0179 & -0.0021 & 0.0021 \\ -0.0021 & 0.0011 & -0.0012 \\ 0.0021 & -0.0012 & 0.0012 \end{pmatrix}$$

Okpai cost functions for the various units are represented by F_1 to F_3 respectively.

$$F_1(P_1) = 480.58 + 10.30P_1 + 1.13{P_1}^2$$
$$F_2(P_2) = 480.58 + 10.30P_2 + 1.13{P_2}^2$$
$$F_3(P_3) = 480.58 + 10.30P_3 + 1.13{P_3}^2$$

3.4. Okpai Power Plant using PSO and GA

The loss coefficient of the Okpai power plant otherwise known as the B-matrix. The Okpai B-matrix is a 3x3 matrix which is required to compute the losses in the transmission line for more reasonable and accurate result.

Table 7 and Table 8 contain the optimal power dispatch of Okpai gas power plant employing PSO and GA techniques respectively. The simulation was performed at different load conditions of 315 MW, 350 MW and 385 MW. These load conditions were chosen based on 90%, 100% and 110% loading corresponding to under loading, normal loading and slightly over loading conditions respectively. In each load condition, the optimal power dispatch of each unit, the cost of generation and the transmission losses were obtained.

For the PSO based optimal power dispatch, the transmission losses of 8.17 MW, 9.62 MW and 10.83 MW were obtained at the respective load conditions while total generation costs of N83551.83, N85221.57 and N88151.62 were respectively obtained. Generally, the total generation cost in Tables 5 – 7 increases progressively with rising load demand. This upward trend is expected since higher load levels require greater power output from the generating units, leading to increased fuel consumption, transmission losses and cost. Also, Figure 9 through Figure 11 depicts the convergence graph which is the plot of fitness function against the number of iterations. This graph represents the rate at which the particles searches for an optimal point.

For the GA based optimal power dispatch, the transmission losses of 11.63 MW, 12.15 MW and 13.94 MW were obtained at the respective load conditions while total generation costs of N46554000, N48996000 and N53254000 were respectively obtained. Also, Figure 12 through Figure 13 depicts the convergence graph which is the plot of fitness function against the number of iterations. Tables 9 and 10 represent the summary of results obtained for Egbin and okapi power plants using PSO and GA optimization techniques respectively and it was observed that PSO has better performance than GA. It can also be observed that, the transmission losses and cost of generation is proportional to the power demand. The PSO performed better because it yielded a lower losses of 6.14 MW, 7.44 MW and 8.84 MW at various loading conditions when compared to the GA losses of 7.27 MW, 8.96 MW and 10.16 MW respectively for the Egbin Plant (Table 9). Similar results are shown in Table 10, where it was established that the losses arising from using PSO are much lower than those from GA for the Okpai Plant. The pseudo code used for the GA are presented in Appendices A and B.

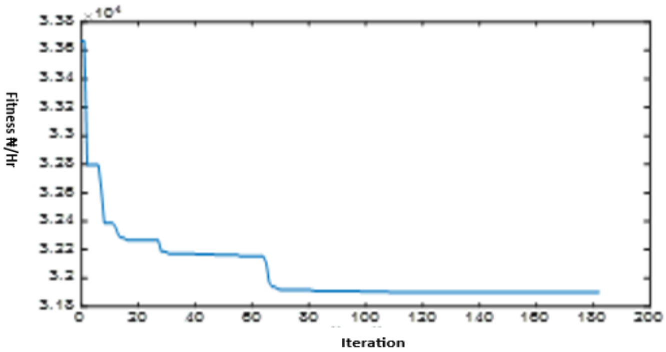

Figure 3: Plot of Fitness against Number of Iterations at 594.9 MW Load

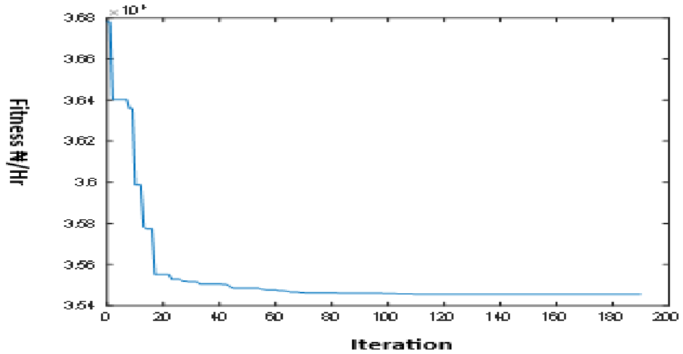

Figure 4: Plot of Fitness against Number of Iterations at 661 MW Load

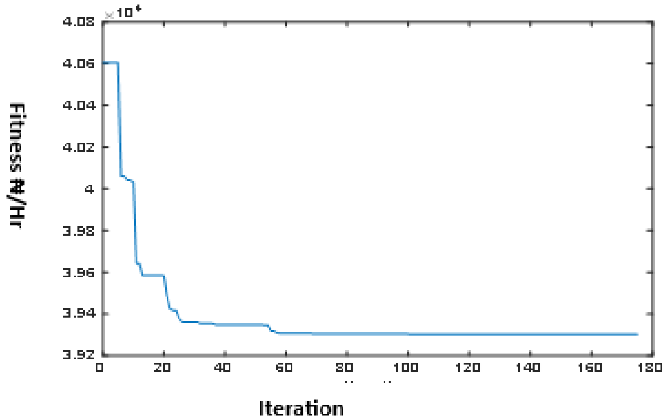

Figure 5: Plot of Fitness against Number of Iterations at 727.1 MW Load

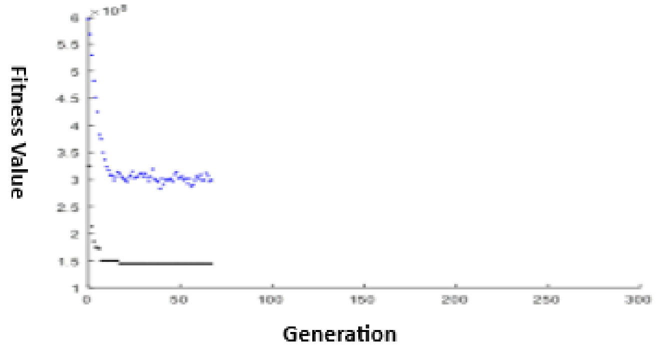

Figure 6: Plot of Fitness against Number of Iterations at 594.9 MW Load

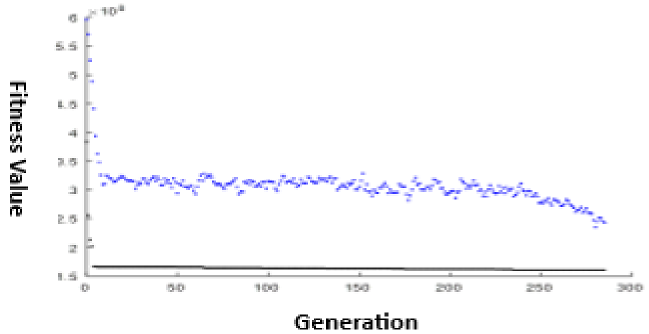

Figure 7: Plot of Fitness against Number of Iterations at 661 MW Load

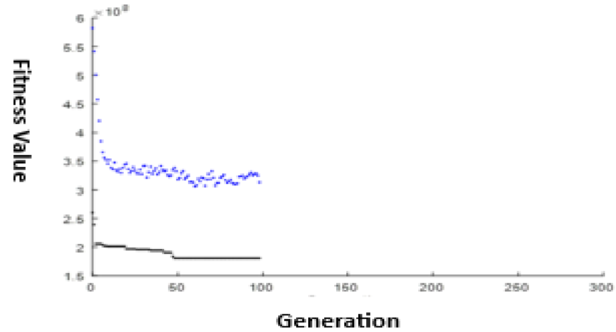

Figure 8: Plot of Fitness against Number of Iterations at 727.1 MW Load

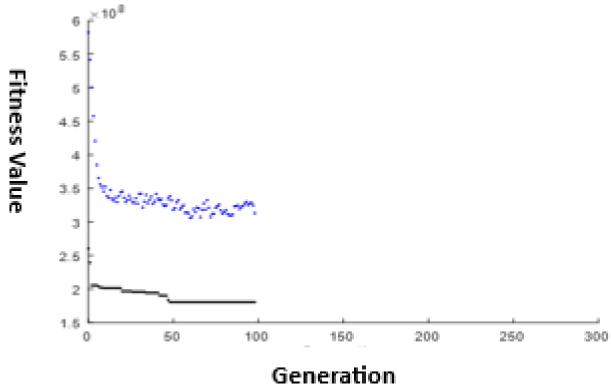

Figure 9: Plot of Fitness against Number of Iterations at 315 MW Load

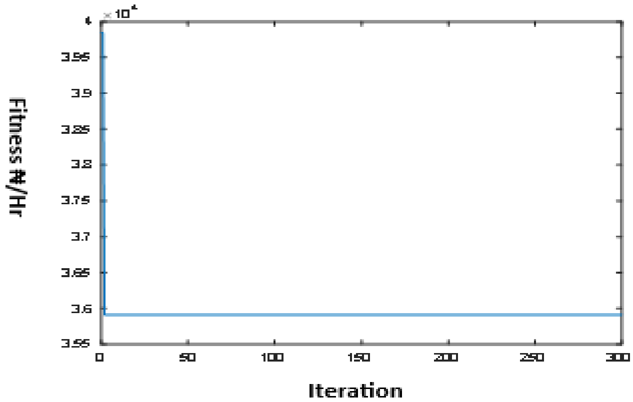

Figure 10: Plot of Fitness against Number of iterations at 350 MW Load

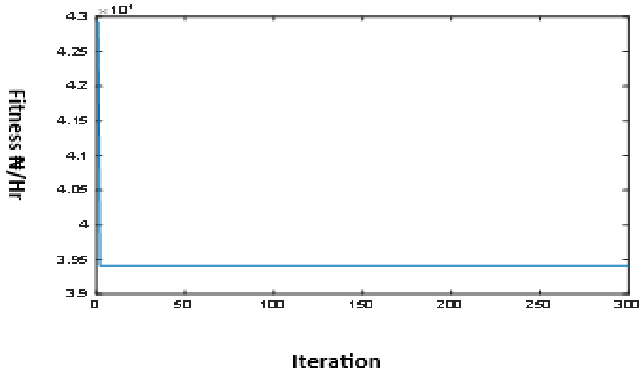

Figure 11: Plot of Fitness against Number of Iterations at 385 MW Load

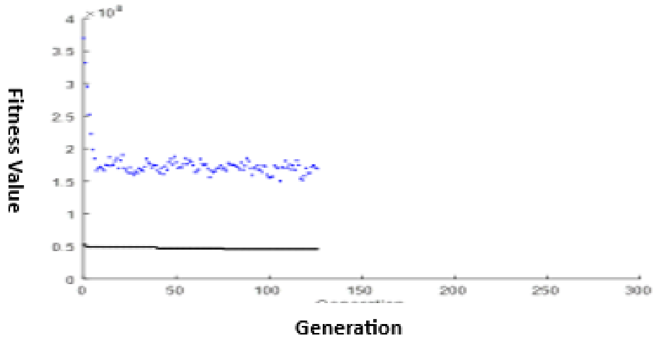

Figure 12: Plot of Fitness against Number of Iterations at 315 MW Load

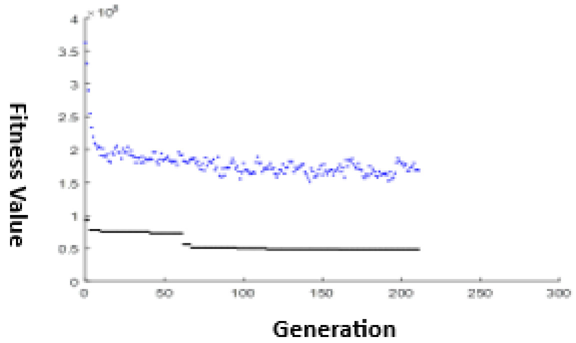

Figure 13: Plot of Fitness against Number of Iterations at 350 MW Load

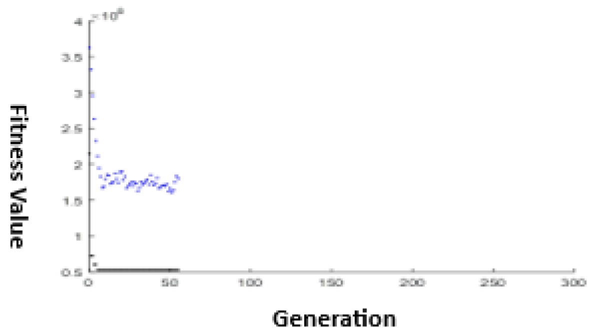

Figure 14: Plot of Fitness against Number of Iterations at 385 MW Load

4. Conclusion

The optimal economic load dispatch of Egbin thermal station and Okpai gas power plant using particle swarm optimization was carried out. The various simulations were validated using genetic algorithm.

The numerical values of the transmission losses as well as the generation cost increases optimally with increase in load demand for the various power plants. It can also be inferred from the above results that, the performance of PSO is better compared to GA in terms of transmission losses and cost of generation for each of the power stations. This shows that, the PSO algorithm has a good convergence property resulting in fuel cost minimization and good evaluation of the fitness function as compared to GA. In order to minimize the transmission losses and the fuel cost consumed by the generating units of Egbin and Okpai power plants, the power flow analyses were carried out and the loss coefficients obtained plus the generating units and cost function data collated were used in MATLAB environment for the optimal economic dispatch problem.

This research has contributed to knowledge in the following ways:

i. Has outlined procedure in operating any power system economically with respect to fuel cost to generate the power needed and return a profit on the capital invested. This is achieved by distributing load among the generating units so that fuel cost is minimized.

ii. Detect and remove system weakness such as low voltages, line overloads by making design studies involving additions to the existing system, to prevent large and problematic reactive power flow, power loss or voltage collapse. The computer-based power flow program would examine the flow between such areas.

iii. It has also been validated that PSO is better than GA in solving economic load dispatch problem.

iv. The possibility of solving economic load dispatch problem considering different types of power plants had also been sufficiently demonstrated.

In conclusion, this study compared the performance of PSO and GA for the economic load dispatch of the Egbin and Okpai Plants using a smooth quadratic cost model. While the results show that both algorithms are effective, several areas remain open for future exploration. In particular, future work could focus on developing a true hybrid version that combines the strengths of PSO and GA, and on extending the model to handle non-differentiable cost functions that include valve-point effects, prohibited operating zones, and ramp-rate limits. Another useful direction would be to move beyond the static dispatch problem to a time-dependent or dynamic scheduling model that captures real operational changes. Finally, broader parameter sensitivity tests and multi-run statistical analyses could help confirm the consistency and robustness of the optimization results across different conditions.

References

[1] A.E Airoboman, P.O Airoboman and F.A Airoboman "Clean Energy Technology for the Mitigation of Climate Change: African Traditional Myth". In: Leal Filho W., Ogugu N., Adelake L., Ayal D., da Silva I. (eds) *African Handbook of Climate Change Adaptation*. Springer, Cham.

[2] A.E. Airoboman, A.O. Salau, and M. Chhabra, "Review of the Performance of the Power Sector in Some Selected African Countries", IEEE Nigercon, 4th International Conference, 17th -19th May, Nile University Abuja, pp. 1-5, 2022.

[3] A.E Airoboman, "Reliability Assessment of Power System Network: A Detailed Review", *International* Journal *of Engineering Technologies,* Vol. 7, Issue 4, pp. 90-103

[4]. D. Bisen, H. M. Dubey, M. Pandit and B. K. Panigrahi, "Solution of Large Scale Economic Load Dispatch Problem using Quadratic Programming and GAMS: A Comparative Analysis" *Journal of Information and Computing Science,* Vol. 7, Issue 3, pp. 200-211, 2012.

[5]. C. Niannian, T. T. N. Nguyen and J. Mitra, "Economic Dispatch in Micro grids Using Multi-agent System", *North American Power Symposium,* pp. 1-5, 2012.

[6] H. M. Dubey, M. Pandit, B. K. Panigrahi and M. Udgir M., "Economic Load Dispatch by Hybrid Swarm Intelligence Based Gravitational Search Algorithm", *International Journal Intelligent Systems and Applications,* Vol. 5, issue 8, pp. 21-32, 2013.

[7]. G. K. Babu and R. K. Samala, "Network and Generator Constrained Economic Dispatch Using Real and Binary Coded Genetic Algorithms", *International Journal of Engineering Research and Applications,* Vol. 3, Issue 5, pp. 1185-1192, 2013.

[8]. V. Karthikeyan, S. Senthilkumar and V. J. Vijayalakshmi, "A New Approach to the Solution of Economic Dispatch Using Particle Swarm Optimization with Simulated Annealing", *International Journal on Computational Sciences and Applications,* vol. 3, issue 3, pp. 37-49, 2013.

[9] O. O. Awodiji, G. A. Bakare, U. O. Aliyu, "Short-Term Economic Load Dispatch of Nigerian Thermal Power Plants Based on Differential Evolution Approach", *International Journal of Scientific & Engineering Research,* Vol. 5, Issue 3, pp. 589-595, 2014.

[10]. K. Balamurugan, R. Muralisachithnndam, and S.R. Krishnan, "Differential Evolution Based Solution for Combined Economic and Emission Power Dispatch with Valve Loading Effect", *International Journal on Electrical Engineering and Informatics,* vol. 6, issue 1, pp. 74-92, 2014.

[11] E. Buraimoh, T. O. Ejidokun and O. J. Ayamolowo, "Optimization of an expanded Nigeria electricity grid system economic using load dispatch", ABUAD Journal of Engineering Research and Development, Vol. 1, Issue 1, pp. 61-66. 2017.

[12] C. Amos, S. Y. Musa and I. T. Thuku, "Particle Swarm Optimization based economic load dispatch of Nigeria hydrothermal considering hydro cost functions", *International Journal of Engineering Science and Computing,* pp. 14690-14696, 2017.

[13]. M.N. Nwohu, and OsaremwindaOsarobo Paul, "Evaluation of Economic Load Dispatch Problem in Power Generating Stations by the Use of Ant Colony Search Algorithms", *International Journal of Research Studies in Electrical and Electronics Engineering,* Volume3, Issue 1, pp. 20-29, 2017.

[14] R. Al-Nahhal, A. F., Naeim and Y. G., Hegazy, "Economic Load Dispatch Problem using Particle Swarm Optimization Technique Considering Wind Power Penetration", *IEEE,* pp. 1-6, 2019.

[15] A. O. Odesola and T. O. Ale, "Overview Of Energy t Jebba Hydropower Station (2009-2016)",*Nigerian Journal of Technology,* Vol. 38, No. 3, pp. 744 – 749, 2019 System considering Valve-Point Loading Effect through Interior point method", *ICEPT,* pp. 1-9, 2022.

[16] M. Okafor and I. Adewale, "Electricity Sector Assessment in Nigeria: The Post-Liberalization Era." *Cogent Engineering,* 9(1).

APPENDIX A: MATLAB CODES FOR GA-BASED ELD FOR EGBIN POWER PLANT

```
% This program solves the economic dispatch with Bmn coefficients by
% Genetic Algorithm
% the data matrix should have 5 columns of fuel cost coefficients and plant
limits.
% 1.a ($/MW^2) 2. b $/MW 3. c ($) 4.lower limit(MW) 5.Upper limit(MW)
%no of rows denote the no of plants(n)

function[ F P1 Pl]=eldga(x)
global data B Pd
x=abs(x);
n=length(data(:,1));
fori=1:n-1
if x(i)>1;
x(i)=1;
else
end
    P(i)=data(i+1,4)+x(i)*(data(i+1,5)-data(i+1,4));
end

B11=B(1,1);
B1n=B(1,2:n);
Bnn=B(2:n,2:n);
A=B11;
BB1=2*B1n*P';
B1=BB1-1;
C1=P*Bnn*P';
C=Pd-sum(P)+C1;
x1=roots([A B1 C]);
```

APPENDIX B: GA TEST

```
clear;
clc;
tic;
global data B Pd

data= [480.58  10.3     1.13    150    600
480.58   10.3     1.13    150    600
480.58   10.3     1.13    150    600];

 B=[0.0040   0.0036   -0.0036
0.0036   0.0059   -0.0059
    -0.0036 -0.0059 0.0059];
% Demand (MW)
Pd=550;
% setting the genetic algorithm parameters.
options = gaoptimset;
options = gaoptimset('PopulationSize', 100,'Generations', 300,'TimeLimit',
200,'StallTimeLimit', 100,'PlotFcns',  {@gaplotbestf});
  [xff]=ga(@eldga,5,options);
[ F P1 Pl]=eldga(x)
tic;
%   F is the total fuel cost
%P1 is the allocation vector
% Pl is the transmission losses
Total_Generation=sum(P1)
```