International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 2, pp: 229-239 www.ijaem.net ISSN: 2395-5252

Optimal Economic Load Dispatch of Nigeria thermal Generating Stations Using Particles Swarm Optimization technique

Chinda Amos[1], Johnson O. Okorhi[2] Tari J. Honda[3] and David A. Mshelia[4]
[1,2,3]National Centre for Technology Management (NACETEM), Modibbo Adama University of Technology (MAUTECH) Yola, Adamawa State.
Corresponding Author: Chinda Amos

Date of Submission: 08-07-2020 Date of Acceptance: 23-07-2020

ABSTRACT: This paper presents an optimization of Economic Load Dispatch (ELD) problem. This is to allocate the total power demand and losses among on-line thermal generating units in order to minimize the cost of generation while satisfying both technical and physical constraints. This network presents the application of Particle Swarm Optimization (PSO) Algorithm to optimally search for solution to a realistically formulated ELD problem. The procedure of PSO algorithm based ELD problem has been implemented on the MATLAB R2013a for windows and then applied to then solve the economic load dispatch of some of the Nigerian thermal power stations. The results obtained were then compared with other published results obtained from Conventional Genetic Algorithm and Differential Evolution. The results revealed that PSO algorithm is more reliable because it produces consistent results after several simulations. The simulation results also procured the least production cost for all the cases considered and hence a better approach to the optimization of ELD problem for the two test systems considered in this work.

KEY WORDS: PSO, ELD, Nigeria Thermal Generating Stations.

I. INTRODUCTION

Electrical power generation, transmission and distribution are the three stages of delivering electricity to consumers at residential, industry, commercial, and administrative areas. The supply of adequate and stable electricity to consumers is the back born of socioeconomic development of any nation. While inadequate and unstable supply of electricity to consumers in any nation would definitely lead that nation backward in terms its socio-economic growth. Like any other economic sector in Nigeria, the power sector has its peculiar problems. In fact the sector has multidimensional problems. Looking at electric trend of power system from inception starting from little utility networks, the use of electricity has grown bigger. Now, electric power systems became widespread and complex in nature. From its inception to present, power system utilization has pass through different stages. Generating stations are not at equal distance from each other or having equal fuel cost functions. Therefore to provide cheaper power, load has to be distributed among the various generating stations in order to minimize the cost of generation [1, 2].

Electric power utilities is aimed to providing better quality and reliable power to consumers at a cheaper cost while meeting the operating limits of generators and satisfying its constraints. This formulates the economic load dispatch problem for determining the optimal combination of the power output of all the online generators which minimizes the total fuel cost [3]. Traditional algorithms like gradient method, lambda iteration and Newton method would have solve economic load dispatch problems if the fuel-cost curves of the generating units are piece-wise linear and monotonically increasing. But in reality the input-output characteristics of the generating units are non-smooth, non-linear, and discrete in nature resulting to prohibited operating zones, ramp rate limits and multi fuel effects [4]. Thus the resultant ELD becomes a challenging non-convex optimization problem, which is difficult to solve using the traditional methods [5].

A lot of stochastic meta heuristic approaches such as particle swarm optimization (PSO), evolutionary programming (EP), differential evolution (DE), genetic algorithm (GA), artificial neural network (ANN), simulated annealing (SA), ant colony (ACS), tabu search (TS), firefly algorithm (FA), Cuckoo Search (CS) etc have been developed for solving both linear and non-linear economic load dispatch problems [6-10]. In this paper, particle swarm optimization (PSO) algorithm is proposed to solve the ELD problems in power systems. The viability of the method is analyzed for its accuracy and rate of convergence on the Nigerian power network (1999 model) and results were compared with other heuristics methods.

II. POWER SYSTEM IN NIGERIA

The electrical power demand in Nigeria is more than what is generated in the country with the availability of all the natural resources in the country. This is one of the reasons why the country's development is stunted and epileptic in nature which prolongs her development and risks losing potential investors. Constant power supply is the hallmark of a developed economy.

Constant and reliable production of power is critical to the profitability of electricity utilities. This can only be realized when the power generators are scheduled efficiently to meet electricity demand. The main factors to be considered for the economic operation of the system are efficiency of generating unit, the transmission loses and the operating costs. Economic load dispatch has been applied to obtain optimal fuel cost to the systems while satisfying their constraints. In recent years, the Power Holding Company of Nigeria (PHCN) has been experiencing serious problem in generation, transmission, distribution, maintenance, financial constraints and increase in power demand, considering the generation/power demand problems, several units were on emergency/forced outages, which led to system disturbance such as; partial and total system collapse. These problems were attributed to over stressing the units to generate outside their normal operating conditions [11, 12]. This will thus lead to generating electric power at loss. With regards to these problems, it is required to study the cost functions of the available thermal units, the country's maximum power demand, and the power limits in order to carry out the economic load dispatch problem.

The aim of this paper is to apply a particle swarm optimization technique to solve the economic load dispatch (ELD) problem of Nigeria thermal power plants for optimal allocation of the total power demand among the available generating units so as to minimize the total generation cost subject to system constraints.

III. STATEMENT OF THE PROBLEM

Consider a system consisting of n-thermal generating units connected to a transmission network as shown below.

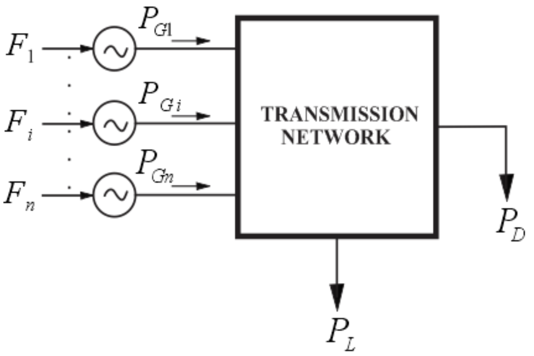


Figure 1: interconnected power system network

Where;

F_i is the fuel cost of unit i

P_{Gi} is the power delivered by unit i

P_L is the total power loss

The quadratic cost function of unit i is given by

$$F_i(P_{Gi}) = \alpha_i + \beta_i P_{Gi} + \gamma_i P_{Gi}^2 \qquad (1)$$

Where;

α_i is the constant cost coefficient of unit i

β_i is the linear cost coefficient of unit i

γ_i is the quadratic cost coefficient of unit i

The economic load dispatch is aimed at minimizing the total fuel cost of power system subject to generation constraints. This can be expressed as

$$F_T = \sum_{i=1}^{n} F_i(P_{Gi}) \qquad (2)$$

Where

F_T is the total cost of power generation

$F_i P_{Gi}$ is the generation cost of unit i

The minimization equation (2) is further subject to the following constraints:

a. Equality constraints

$$\sum_{i=1}^{n} P_{Gi} = P_D + P_L \qquad (3)$$

Using the B – coefficient method, network losses are expressed as:

$$P_L = P_{Gi}^T \, B \, P_{Gi}$$

(4)

Where B is the loss coefficient

b. Inequality constraints

$$P_{Gi}^{min} \leq P_{Gi} \geq P_{Gi}^{max}$$

(5)

Where

P_{Gi}^{min} is the minimum power limit of unit i

P_{Gi}^{max} is the maximum power limit of unit i

The research on application of particle swarm optimization to economic load dispatch is modeled using the quadratic cost function and was applied to the coordination of the Nigerian thermal power plants. The issues of valve-point effect, ramp-rate limits, environmental constraints, and piecewise linear cost function are out of scope of this paper.

IV. LITERATURE REVIEW

Complex constrained problems of economic load dispatch is addressed by intelligent methods; some of them are particle swarm optimization (PSO), genetic algorithm (GA), adaptive Hopfield neural network (AHNN) dynamic programming (DP), tabu search, hybrid evolutionary programming (HEP), evolutionary programming (EP), neural network (NN), etc. Below is a review of related literature and study of economic load dispatch of generators considering various constraints in power system.

[1] (Puri et al, 2016) Shows how the formation of Economic Load dispatch (ELD) problem plays a significant role in the functioning of electrical power systems. It is used in determining the optimal cost for satisfying the demand with available electric generation resources. The ELD problem of thermal units results in significant saving for electrical utilities.

[4] (Kaur and Kuamr, 2014) discussed the planning of power output for each devoted generator unit in such a way that the operating cost is minimized and simultaneously matching load demand, power operating limits and maintaining stability as the problem of economic dispatch in power system. This problem becomes more complex in large scale power systems as it is hard to find out optimal solution because it is non linear function and it contains number of local optimal.

[5] (Nema and Gajbhiye, 2014) describe and Introduce a new nature Inspired Artificial Intelligence method called Firefly Algorithm(FA) as a stochastic Meta heuristic approach based on the idealized behavior of the flashing characteristics of fireflies. The aim is to minimize the generating unit's combined fuel cost having quadratic cost characteristics subjected to limits on generator real power output & transmission losses. The paper presents an application of the FA to ED with valve point loading for different Test Case system and the solution looks promising to GA.

[6] (Karthik and Reddy, 2014) describe economic dispatch as the process allocating optimal load to each committed generators while satisfying the equality and inequality constraints by minimizing the fuel cost by maintaining the generation power in limits and to reduce the computational time using Particle Swarm Optimization PSO.

[7] (Kolli and Bhavana, 2015) looks at the conventional methods as fast but not that efficient as assumed cost curves of the generating units to be piece wise linear functions but with the advent of high speed computing devices, Particle Swarm Optimization PSO has gained prominence with better result but currently Nature Inspired Meta-Heuristic method such as Cuckoo Search seems to beget best results.

[8] (Makkar and Kaur, 2016) Describe Economic load dispatch as a sub problem of the optimal power flow having the objective of fuel cost minimization. In real situations the fuel cost equations are non-convex and sometimes non-continuous. In order to solve such economic load dispatch problems, various methods are discussed and the results of these methods are compared.

[10] (Sudhakaran et al, 2007) developed Particle Swarm Optimization PSO through simulation of a simplified social system and has been found to be robust in solving continuous non linear optimization problems due to accuracy and less time consuming. Later it was compared with conventional method and Genetic Algorithm GA, and it was observed that PSO is reliable.

i. Heuristic Optimization Technique

The recently introduced particle swarm optimization (PSO), simulated annealing, genetic algorithms, differential evolution and tabu search are the heuristic optimization techniques with powerful solution schemes to obtain the global optimums in power system to solve optimization problems serve as alternative to the conventional mathematical approaches.

ii. Particle Swarm Optimization

Particle swarm optimization (PSO) is the tool chosen as a technique for the actualization of this work. Russel Ebenhart (Electrical Enineer) and James Kennedy (Social Psychologist) in 1995, developed out of attempts to model bird flocks and fish schools Inspired by the social behavior of birds, studied by Craig Reynolds (a biologist) in late 80s and early 90s develops particle swarm optimization [13]. This was later used in computer simulations of virtual birds recognized for suitability technique for optimization.

PSO simulates the behaviours of bird flocking. Suppose the following scenario: a group of birds are randomly searching food in an area. There is only one piece of food in the area being searched. All the birds do not know where the food is. But they know how far the food is in each iteration. So what's the best strategy to find the food? The effective one is to follow the bird, which is nearest to the food. PSO learned from the scenario and used it to solve the optimization problems.[2]

In PSO, each single solution is a "bird" in the search space. We call it "particle". All of particles have fitness values, which are evaluated by the fitness function to be optimized, and have velocities, which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles. PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. In every iteration, each particle is updated by following two "best" values. The first one is the best solution (fitness) it has achieved so far. (The fitness value is also stored.) This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the population. This best value is a global best and called gbest. Particle swarm optimization has been found to be extremely effective in solving a wide range of engineering problems and solves them very quickly.

V. APPLICATION OF PSO IN ELD

The aim of this research is to distribute the total power demand among the available thermal generating stations to minimizing the total fuel cost subject to both equality and inequality constraints as earlier stated in Eqns. (1) - (3) and Particle Swarm Optimization was used to achieve this desired goal. The solution of the ELD problem using the classical approach presents some limitation in its implementation. One of such limitation is that the Lamda-iteration method assumes the cost coefficient to be a continuous function. The method breaks down when it is applied to a discontinuous function with prohibited zones or larger steam turbine generating units [1]. Again, there is a tendency for this method to converge at a local minimum when the power system operating status is far outside the normal situation, for instance during and after large disturbances. For this purpose, the Particle Swarm Optimization technique was applied in this paper to solve an ELD problem in order to eliminate the limitation of the Lamda-iterations enumerated above.

Let Generators represent the warm and birds (particles) with active power, reactive power and all other parameters as the velocity which directs the flying of the particles through the problem space by following the current optimum particles. Therefore, let *p* and *v* denotes a particle's coordinate (position) and its corresponding flight speed (velocity) in a search space, respectively. Therefore, the j^{th} particle is represented as $P_i = [P_{i1}, P_{i2}, P_{i3}, \ldots\ldots\ldots, P_{iNG}]$ in the NP dimensional space. The best previous position of each particle is recorded and represented as $Pb_i = [Pb_{i1}, Pb_{i2}, Pb_{i3}, \ldots\ldots\ldots, Pb_{iNG}]$. The index of best particle among all the particles in the group is represented by the $[G_1, G_2, G_3, \ldots\ldots\ldots, G_{NG}]$. The velocity of the particle is represented as $V = [V_{i1}, V_{i2}, V_{i3}, \ldots\ldots\ldots, V_{iNP}]$. The modified velocity and position of each particle can be calculated using the current velocity and the distance from Pbij to Gj as shown in the following formulas [14].

$v_{ij}^{r+1} = wv_{ij}^{r} + C_1R_1(pb_{ij}^{r} - p_{ij}^{r}) + C_2R_2(G_j^{r} - p_{ij}^{r})$ $(i = 1, 2,\ldots,NP;\ j = 1, 2,\ldots.,NG)$
(6)

$p_{ij}^{r+1} = p_{ij}^{r} + v_{ij}^{r} - p_{ij}^{r+1}$ $(i = 1,2,3,\ldots\ldots\ldots,NP;\ j = 1, 2,\ldots\ldots..,NG)$
(7)

Where
NP is the number of individuals
NG is the number of generators being evaluated
C_1 and C_2 are the acceleration constants
R_1 and R_2 are uniform random values in range (0.1)
v_{ij}^{r} is the velocity of j^{th} member of i^{th} particle at r^{th} iteration, $v_j^{min} \leq v_{ij}^{r} \leq v_j^{max}$
P_{ij}^{r} is the current position of j^{th} member of i^{th} particle at r^{th} iteration.

In the above procedure, the parameter v_j^{min} determined the resolution, or fitness with which regions are to be searched between the present position and the target position. If v_j^{max} is too high, particles might fly past good solutions. If v_j^{max} is too small, particle may not explore sufficiently beyond local solutions. In many experiences with PSO, v_j^{max} was often set at (10 – 20) % of the dynamic range of the variable on the variable of each dimension. The constant C_1 and C_2 rep resents the weighting of the stochastic acceleration term that put each particle towards the pb_{ij}^{r}, G_j^{r} positions. Low values allow particles to roam far from the target region before being tugged back. On the other hand, high value results in abrupt movement towards or past target regions. Hence, the acceleration constants C_1 and C_2 were often set to be 2.0 according to past experiences [14]. The above equations are written as

$v_{ij}^{new} = wv_{ij} + C_1R_1(p_{ij}^{best} - p_{ij}) + C_2R_2(G_j^{best} - p_{ij})$ $(i = 1, 2,..,NP;\ j = 1, 2,..,NG)$
(8)

$p_{ij}^{new} = p_{ij} + v_{ij}^{new}$ $(i = 1, 2,\ldots,NP;\ j = 1, 2,\ldots..,NG)$
(9)

In the strategy of PSO, the particles best position p_{ij}^{best} and the global best position G_j^{best} are the key factors. The best position out of all p_{ij}^{best} is taken as G_j^{best}. Suitable selection of inertia weight in equation below provides balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution. As originally developed, *w* often decrease linearly about 0.9 to 0.4 during a run. In general inertia weight *w* is set according to the following equation (10) is used in equation (8)

$$W = W_{\max} - \frac{W\max - W\min}{ITER\max} \text{ x } ITER$$

(10)

Where

W is the inertia weight factor

$ITER_{\max}$ is the maximum number of iterations (generation) and

ITER is the current number of iterations.

Eqn. (8) is used to calculate the particle's new velocity according to its previous velocity and the distances of its current position from its own best experience (position) and the group's best experience. Then the particle flies towards a new position according to Eqn. (9). The performance of each particle is measured according to a predefined fitness function, which is related to the problem to be solved.

a. Implementation of PSO for ELD

The main objective of economic dispatch is to obtain the amount of real power to be generated by each committed generator, while achieving a minimum generation cost within the constraints. The particle swarm optimization is implemented by searching the generation of power plants, p_i within generator limits. This section provides the solution methodology to the economic dispatch problems using PSO. The evaluation function for evaluating the minimum generation cost of each individual in the population is adopted as follows:

$$F_T = \sum_{i=1}^{n} F_i(P_{Gi}) \qquad (11)$$

b. Steps of implementation

Step 1: Initialize swarm size

The population is initialized randomly within the restrictive maximum and minimum limits for each of the generating units such that whole of the population thus formed must be satisfying all the constraints.

Step 2: Evaluate Fitness

Initialize the relevant PSO parameters, population size, C1, C2, maximum and minimum inertial weight, maximum and minimum velocity limit, etc. Calculate fitness i.e Pbest (the best value it had obtained so far) and set this fitness equal to local fitness and assign the corresponding positions as local best position

Step3: Compare particle's fitness analysis with particle's pbest;

If the current price is best than pbest, then set pbest price adequate to the present price, and also the pbest location adequate to the present location in the d-dimensional area.

Step4: Compare fitness analysis with the population's overall previous best;

If the current price is best than gbest, then reset gbest to the present particles array index and price.

Step5: amendment the speed of the particle in keeping with equation (8)

$$v_{ij}^{new} = wv_{ij} + C_1R_1\,(p_{ij}^{best} - p_{ij}) + C_2R_2(G_j^{best} - p_{ij});(i = 1, 2,..,NP;\ j = 1, 2,..,NG)$$

Where

W is an inertia weight value

R_1 and R_2 is the random number between 0 and 1

C_1 and C_2 are acceleration factors

p_{ij}^{best} is the best position for individual particle which yields lowest cost over all generations

G_j^{best} is the location of best particle in the entire population of all generations

The acceleration constants C_1 and C_2 in equation (1) represent the coefficient of the random acceleration terms that pull every particle toward pbest and gbest positions. Speed Vmax was, therefore, the sole parameter we regularly set it at regarding 10-20% of the dynamic vary of the variable on every dimension.

Step6: modification the position of the particle according to equation (9)

After the velocity is updated, the new location of j_{th} individual at the i_{th} dimension can be calculated as

$$p_{ij}^{new} = p_{ij} + v_{ij}^{new} \qquad (i = 1, 2,\ldots\ldots\ldots,NP;\ j = 1, 2,\ldots\ldots..,NG)$$

In the strategy of PSO, the particles best position p_{ij}^{best} and the global best position G_j^{best} are the key factors. The best position out of all p_{ij}^{best} is taken as G_j^{best}. Suitable selection of inertia weight in equation below provides balance between global and local explorations, thus requiring less iteration on average to find a sufficiently optimal solution. As originally developed, *w* often decrease linearly about 0.9 to 0.4 during a run

Step7: Loop to step two till a criterion is met, else

The individual that generates the latest gbest is the optimal generation power of each unit with the minimum total generation cost.

VI. SIMULATION RESULTS AND ANALYSIS

The procedure for solving ELD problems for the thermal power plant using Particle Swarm Optimization based has been implemented on Matlab R2013a software for windows. The effectiveness of the programme has been implemented on the Nigerian thermal power plant. The work was carried out on hp laptop computer with the following specifications: Processor: Intel® CPU T4300 @ 2.16GHz installed Memory (RAM): 4.00GB, system type: 32-bit operating system, hard disc: 350GB and windows operating system: windows 7. The stimulation results were presented.

Three different approaches were used by [1] to solve this problem; classical method (CM), hopfield neural network (HNN), micro genetic algorithm (μGA) and conventional genetic algorithm (CGA). They used three sets of power demand PD: 340MW, 850MW and 1150MW to test it on the IEEE 3 generating units, 6 bus test system before implementing on the Nigeria Thermal Power plant.

Particle swarm optimization was applied to the above test system for obtaining economic load dispatch of similar load requirements and was also implemented according to the flow chart shown above. For each sample load, under the same objective function and individual definition, good number of trials were performed to check the evolutionary process and to compare the quality of their solution and convergence characteristics.

SIMULATION RESULTS IEEE 3 GENERATORS, 6 BUS TEST SYSTEM

In order to test the feasibility of the developed tool, three different sets of power demand P_D: 340MW, 850MW and 1150MW were studied to illustrate the effectiveness of the approach in practical applications using standard IEEE 3 generating units, 6-bus test system obtained from [1, 15]. The coefficients of fuel cost, maximum and minimum power limits are shown in Table 1.

Table 1: IEEE 3 generators, 6-bus test system characteristics

Generating units parameters					
Unit No.	Constant Cost Coefficient α	Linear Cost Coefficient β	Quadratic Cost Coefficient γ	P_{Gi}^{min} (MW)	P_{Gi}^{min} (MW)
1	561	7.92	0.001562	150	600
2	310	7.85	0.00194	100	400
3	78	7.97	0.00482	50	200

Source: (Yalcinoz and Short, 1997)

The results obtained for the proposed PSO based ELD with P_D = 340MW, 850MW and 1150MW are compared with the Classical Method and Genetic Algorithm (GA) [1, 15] as shown in table 2, 3 and 4 respectively. Whereas, figures 2, 3 and 4 shows their convergence characteristics.

Table 2: Comparative results for test system with results obtained by [1, 15] P_D = 340MW

	Methods of solution		
Parameters	Classical Method	Genetic Algorithm	Particle Swarm Optimization
Power output of unit 1 P_{G1t} (MW)	152.19	165.06	166.09
Power output of unit 2 P_{G2t} (MW)	140.58	122.90	118.16
Power output of unit 3 P_{G3t} (MW)	50.00	54.59	58.15
Total power output $\sum P_{Gt}$ (MW)	342.77	342.55	342.40
Power demand P_D (MW)	340.00	340.00	340.00
$P_D + P_L$ (MW)	342.76	342.53	342.40
Total Cost $/hr	3742.9	3742.21	3742.04

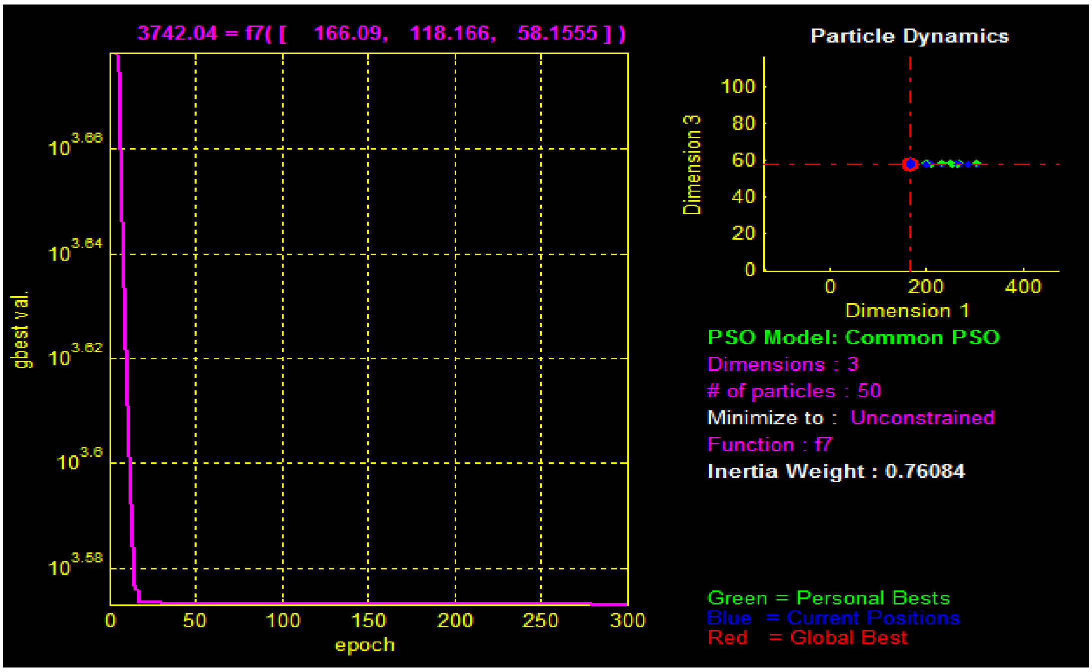


Figure 2: Convergence characteristics of PSO based ELD for test system (P_D = 340MW)

Table 3: Comparative results for test system with results obtained by [1, 15] P_D = 850MW

Parameters	Methods of solution Classical Method	Genetic Algorithm	Particle Swarm Optimization
Power output of unit 1 P_{G1t} (MW)	401.22	399.64	450.04
Power output of unit 2 P_{G2t} (MW)	341.08	320.80	282.21
Power output of unit 3 P_{G3t} (MW)	124.67	146.18	132.55
Total power output $\sum P_{Gt}$ (MW)	866.97	866.62	864.80
Power demand P_D (MW)	850.00	850.00	850.00
$P_D + P_L$ (MW)	867.14	866.62	864.80
Total Cost $/hr	8351.40	8349.58	8340.69

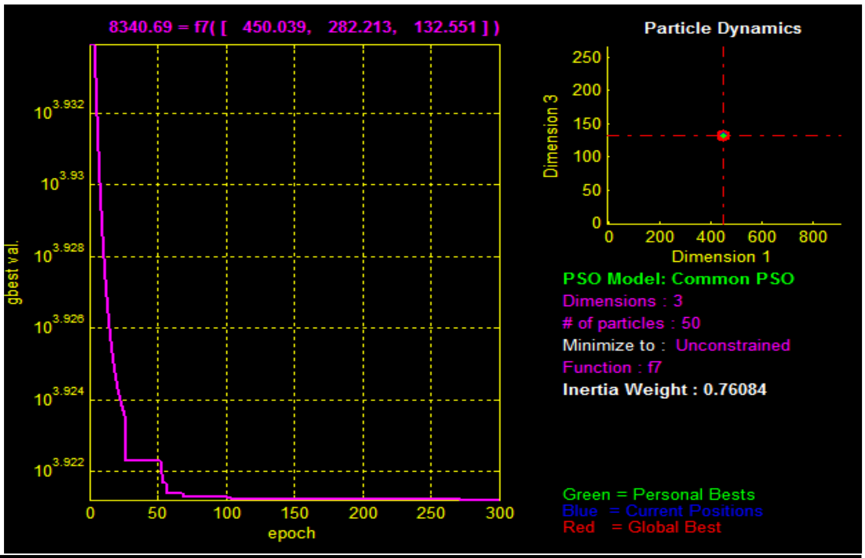
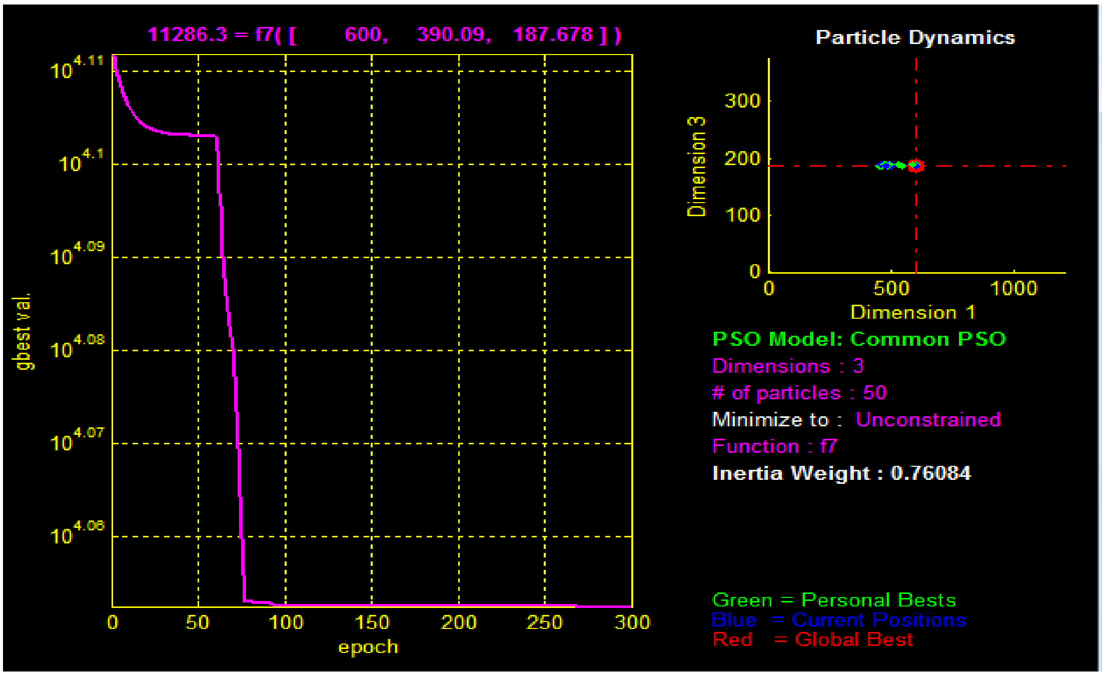


Figure 3: Convergence characteristics of PSO based ELD for test system (P_D = 850MW)

Table 4: Comparative results for test system with results obtained by [1, 15] for $P_D = 1150MW$

Parameters	Methods of solution Classical Method	Genetic Algorithm	Particle Swarm Optimization
Power output of unit 1 P_{G1t} (MW)	592.33	596.35	600.00
Power output of unit 2 P_{G2t} (MW)	400.00	399.10	390.09
Power output of unit 3 P_{G3t} (MW)	186.77	183.60	187.67
Total power output $\sum P_G$ (MW)	1179.10	1179.05	1177.76
Power demand P_D (MW)	1150.00	1150.00	1150.00
$P_D + P_L$ (MW)	1179.10	1179.05	1177.76
Total Cost $/hr	11295.00	11295.30	11286.30



PSO Model: Common PSO
Dimensions : 3
# of particles : 50
Minimize to : Unconstrained
Function : f7
Inertia Weight : 0.76084

Figure 4: Convergence characteristics of PSO based ELD for test system (P_D = 1150MW)

SIMULATION RESULTS OF THE NIGERIAN POWER SYSTEM

The PSO based ELD was first verified on a standard IEEE 3 generating units, 6-bus test system to study the viability of the developed tool. This was later applied to the coordination of Nigerian thermal generating stations based on the data obtained from [1, 2] with single line diagram shown in figure 5. Table 5 presents the cost coefficients of the four Nigerian thermal power stations and their minimum and maximum loading limits. The Nigerian power system grid is essentially a 31-bus, 330-kV network interconnecting four thermal generating stations and three hydro stations to the various load points.

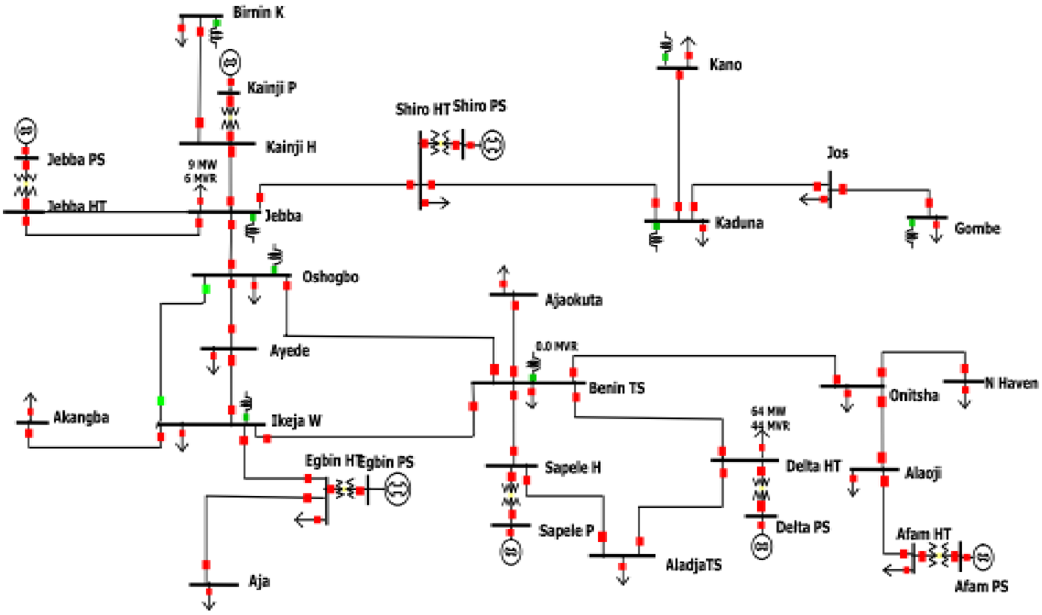


Figure 5: Single line diagram of Nigeria 330kV 31-bus grid systems

Table 5: PHCN thermal generating stations characteristics [1]

Generating Units Parameters					
Stations	Constant Cost Coefficient α	Linear Cost Coefficient β	Quadratic Cost Coefficient γ	P_{Gi}^{min} (MW)	P_{Gi}^{min} (MW)
Egbin	1278.00	13.10	0.031	275.00	1100.00
Afam	1998.00	56.0	0.092	135.00	540.00
Delta	525.74	-6.13	1.20	75.00	300.00
Sapele	6929.00	7.84	0.13	137.50	550.0

Table 6: Results of PHCN ELD considering losses compared with other techniques

	Methods of solution		
Power Stations	Genetic Algorithm	Differential Evolution	Particle Swarm Optimization
Egbin P_{G1} (MW)	814.56	818.08	1083.15
Afam P_{G2} (MW)	230.82	318.36	187.98
Delta P_{G3} (MW)	69.51	68.00	75.00
Sapele P_{G4} (MW)	457.79	265.93	323.36
Total thermal power generated $\sum P_G$ (MW)	1572.68	1570.37	1669.94
Thermal power P_D (MW)	1572.68	1570.37	1600.00
Kainji (MW)	350	350	350
Shiroro (MW)	490	490	490
Jebba (MW)	450	450	450
Total power generated (MW)	2862.68	2860.37	2959.94
Total power demand P_D (MW)	2823.10	2823.10	2890.00
Total network losses P_L (MW)	130.28	129.26	117.45
$P_D + P_L$ (MW)	2953.38	2952.36	3007.45
Total Cost $/hr	116946.55	107430.00	101814.00

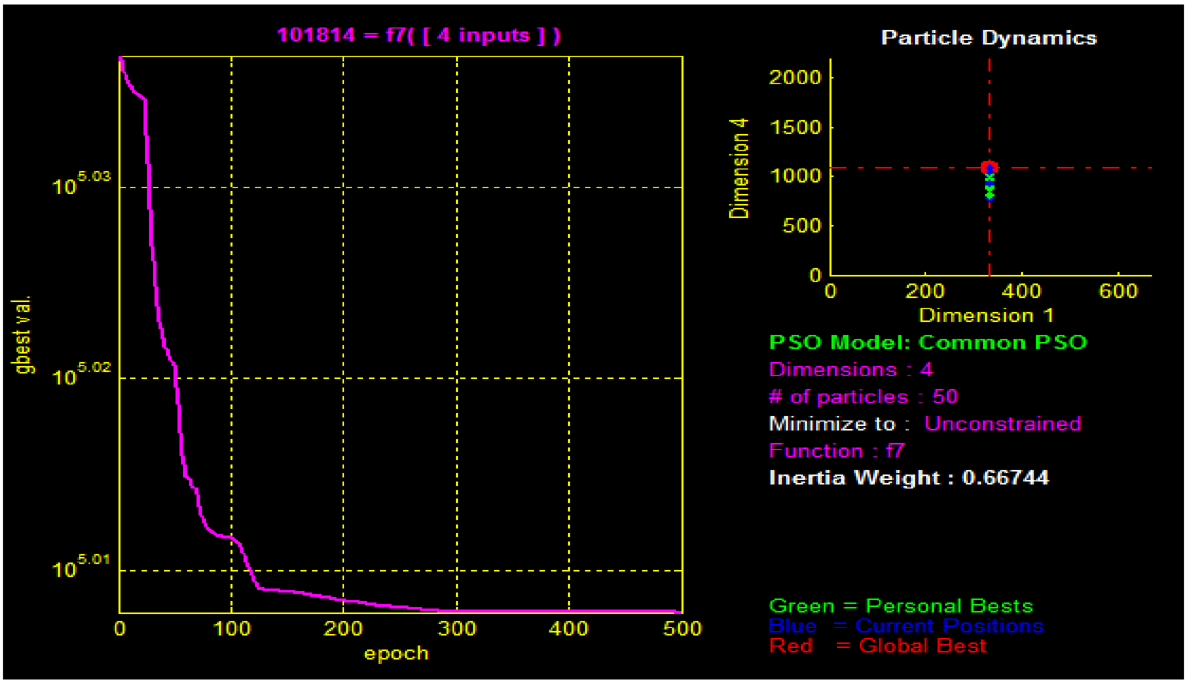


Figure 6: Convergence characteristics of PSO based ELD for Nigeria grid system (P_D = 2890MW)

VII. CONCLUSION

ELD problem was successfully solved using particle swarm optimization. The comparison of results for the 31-bus Nigerian grid system clearly shows that PSO is more reliable, high quality, efficient and hence a better approach to the optimization of ELD problem for the system. Almost all generation costs obtained by the PSO method were lower, thus verifying that the PSO method has better quality of solution and convergence characteristic. From the results obtained, the proposed PSO technique minimizes the total production cost and transmission losses better than GA and DE, except in some cases where the DE also performed equally well.

REFERENCE

[1] G. A. Bakare, U. O. Aliyu, G. K. Venayagamoorthy, and Y. K. Shu'aibu, "Genetic Algorithms Based Economic Dispatch with Application to Coordination of Nigerian Thermal Power Plants," *IEEE Transactions on power systems*, p. 6, 2005.

[2] A. Chinda, "Application of Particle Swarm Optimization in Solving Economic Load Dispatch Problem of Nigeria Electrical Power System," Modibbo Adama University of Technology Yola, 2017.

[3] V. Puri, Y. K. Chauhan, and N. Singh, "Economic Load Dispatch Problem using Particle Swarm Optimization with Inertial Weight and Constriction Factor," *Thammasat International Journal of Science and Technology*, vol. 21, p. 9, 2016.

[4] G. Kaur and D. Kuamr, "Economic Load Dispatch Problem Using Particle Swarm Optimization Technique: A Review," *An International Journal of Engineering Sciences*, vol. 3, p. 6, 2014.

[5] P. Nema and S. Gajbhiye, "Application of artificial intelligence technique to economic load dispatch of thermal power generation unit," *International Journal of Energy and Power Engineering*, vol. 3, p. 6, 2014.

[6] M. V. Karthik and D. S. Reddy, "Particle Swarm Optimization to solve Economic Dispatch Considering Generator Constraints," *The International Journal of Engineering and Science*, p. 7, 2014.

[7] J. Kolli and K. Bhavana, "Comparative Study to Solution of Economic Load Dispatch - Using Evolutionary Algorithms," *International Journal of Emerging Trends in Electrical and Electronics*, vol. 11, p. 5, 2015.

[8] P. K. Makkar and A. kaur, "Different Comparison of Heuristic Algorithms to Solve Economic Load Dispatch: A Literature Review," *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, vol. 4, p. 3, 2016.

[9] A. Tikalkar and M. Khare, "Economic Load Dispatch Using Linearly Decreasing Inertia

Weight Particle Swarm Optimization,," *International Journal of Emerging Technology and Advanced Engineering,* vol. 4, p. 6, 2014.

[10] M. Sudhakaran, P. Ajay, D.-V. Raj, and T. G. Palanivelu, "Application of Particle Swarm Optimization for Economic Load Dispatch Problems," presented at the The 14th International Conference on Intelligent System Applications to Power Systems, Kaohsiung, Taiwan, 2007.

[11] F. Oladipo and O. T. O, "The Nigerian Power System Till Date: A Review," *International Journal of Advance Foundation and Research in Science & Engineering,* vol. 1, p. 14, 2014.

[12] N. Oshogbo, "PHCN Daily Operational Report," 2017.

[13] J. Kennedy and R. Eberhart, "Particle Swarm Optimization," *Proc. of IEEE International Conf. on Neural Networks,* vol. 4, p. 7, 1995.

[14] D. P. Kothari and J. S. Dhillon, *Power System Optimization*, Second ed.: PHI Learnig Private Limited, 2010.

[15] A. J. Wood and B. F. Wollenberg (1984). *Power Generation, Operation and Control*. John Wiley and Sons Inc, New York.

International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 02 Issue: 01 DOI: 10.35629/5252

www.ijaem.net
Email id: ijaem.paper@gmail.com