Premier Journal of Engineering and Applied Sciences
Publication of Nigerian Society of Engineers, Ibadan Branch
P J E A S
Vol. 2, No. 2, 2021 ISSN:2734-3170

# Application of Particle Swarm Optimization Method to Economic Dispatch of Nigerian Power System Considering Valve-Point Loading Effect

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**ARTICLE INFO**

*Received: December, 2020*
*Accepted: March, 2021*
*Published: April, 2021*

**Keywords:**
Economic Dispatch
Valve Point Loading Particle
Swarm Optimization
Nigerian Power System

**ABSTRACT**

*Economic Dispatch (ED) is a procedure which schedules optimal combination of generating stations in a power system to keep down whole cost under equality and inequality constraints. Accurate and practical ED solutions are obtained when the valve-point loading effects of generators are considered. This work presents the ED solution of Nigerian power system considering valve-point loading effect using Particle Swarm Optimization (PSO). The result of the work was compared with previous works that used Genetic Algorithm. It was observed that PSO gave a better result for the ED problem of the Nigerian power system.*

## 1. INTRODUCTION

Optimization process provides the best possible decision variable values when modelled through an objective function, conditioned to some set of limitations (Shrivastava and Siddique, 2014). The general structure, classifications and solution methods of optimization have been reviewed comprehensively by Tijani *et al.* (2019). Optimization solution approaches have been classified as deterministic and nondeterministic optimization methods (Frank *et al.*, 2012). Deterministic optimization methods include Quadratic Programming, Interior Point Method, Gradient method, Linear Programming, Nonlinear Programming and Newton's method (Lavei and Low, 2012; Tijani *et al.*, 2019). The non-deterministic methods comprise Particle Swarm Optimization (PSO), Ant Colony Optimization, Genetic Algorithm (GA) and Evolutionary Algorithm among others (Padya and Joshi, 2008).

By definition, Economic Dispatch (ED) is an optimization issue that primarily allocates the gross output load demand in a power system between available participating generating units in a way that the aggregate price of operation of the generating units is minimized, subject to system constraints (Thanathip, 2004; Thakral and Rai, 2012). ED constitutes one of the highest important problems involving optimization in planning and operations of power systems, while it is of great importance that it must be quickly and adequately solved.

Numerous factors are considered in solving ED problems to realize improved results. These factors include transmission loss of the power system, power flow limitations, valve-point loading effects (VPE), ramp-rate limits and prohibited zones. VPE has an enormous influence on the accuracy of ED solution. Quadrature functions are traditionally used as the cost function which are rise monotonously in the objective function of the ED problem solution. However, quadrature functions are no longer adequate to describe the characteristics of ED problem (Zou *et al.*, 2016). Traditional assumptions of neglecting VPE in ED solutions have resulted in inaccuracies in resulting dispatch (Liu and Cai, 2005). The input-output features of present-day power units are usually nonlinear owing to VPE (Roy *et al.*, 2013). Consideration of VPE in solving ED problem results in accurate and practical EDP solution (Jadoun *et al.*, 2014).

Economic Dispatch Problem (EDP) of Nigerian power system has been greatly researched and numerous optimization methods, both deterministic and non-deterministic methods, have been applied. These methods include GA (Haruna *et al.*, 2004; Bakare *et al.*, 2005; Orike and Corne, 2013; Olakunle and Folly, 2015; Oluwadare *et al.*, 2016; Okozi *et al.*, 2019), PSO (Ibe *et al.*, 2014; Attai, 2015; Amos *et al.*, 2017; Haruna *et al.*, 2017; Haruna *et al.*, 2018), Differential Evolution (Olakunle *et al.*, 2014), Lambda Iteration method (Buraimoh *et al.*, 2017), Ant Colony Optimization (Nwohu and Osaremwinda, 2017), Firefly Algorithm (Ajenikoko *et al.*, 2018) and Simulated Annealing (Abanihi and Ovabor, 2019).

Literature survey shows that EDP solution of Nigerian power system using PSO has been extensively carried out but consideration of VPE on the system has not been adequately considered (Ade-Ikuesan *et al.*, 2019). This work therefore applies PSO to resolve the ED problem of Nigerian power system considering VPE. PSO is chosen because it deals effectively with discrete power system variables, it is robust, simple and easy to implement (Raju *et al.*, 2009). Although, both PSO and GA can handle arbitrary cost functions, PSO carries out the task with a much simpler implementation (Boeringer and Werner, 2004).

## 2. METHODOLOGY

### 2.1 Economic Dispatch Problem

The EDP is a branch of economic operation and security constrained power system categorized into ED and Unit Commitment (UC). Although, UC is an offline problem contrary to ED which is an online problem where all committed generating units are allocated with the aim of satisfying load demands of customers under a given operational conditions (Osaremwinda *et al.*, 2017). High fuel costs and transmission losses are some of the factors that influence EDP (Karakantantis and Vlachos, 2015). The EDP finds the real power generation for all plant in a way that the objective function i.e. the total cost production is derived using the equation 1 (Al-Farsi *et al.*, 2015). The working cost of every generator when generating a particular output is modelled as in eequation 2 (Tchapda *et al.*, 2017). Equation 1 is then written as given in equation 3.

$$\min \ \mathrm{F_{cost}} = \sum_{i=1}^{N_g} F_i(P_i) \tag{1}$$

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \tag{2}$$

$$\mathrm{F_i}(P_i) = \sum_{i=1}^{N_g} a_i + b_i P_i + c_i P_i^2 \tag{3}$$

Where;

$a_i, b_i, c_i$ = price coefficients of the ith generating unit.

$\mathrm{F_i(P_i)}$ = price function of the i$^{th}$ generating unit (in dollars/hour)

$\mathrm{P_i}$ = price power output of the i$^{th}$ generating unit (in MW)

$\mathrm{N_g}$ = number of generators in the system.

The generating constraints are (Mehta and Singh, 2018);

(i) System Equality Constraints

This is given by the following equation 4.

$$\sum_{i=1}^{N_g} P_i = P_D \tag{4}$$

Where;

$P_D$ = system total power demand

(ii) System Inequality Constraints

System inequality constraints are the limits put on the system components and operations. The most important one is the power generation limits given in equation 5.

$$P_i^{min} \le P_i \le P_i^{max} \qquad i = 1,2,\ldots Ng \tag{5}$$

Where;

$P_i^{min}$ = minimum power limit

$P_i^{max}$ = maximum power limit

### 2.2 Transmission Loss in Economic Dispatch Problem

It is most appropriate to consider the total system transmission loss in the economic allocation between different participating generation units. This consideration leads to economical way of generation dispatch in power systems (Chakrabarti and Hadler, 2010). The power balance equation is such that the summation of the power output from all generators are required to be identical with total load demand and total power losses in the system (Shalini and Lakshmi, 2014). The power balance equation is the constraint equation stated in (6).

$$\sum_{i=1}^{Ng} P_i = P_D + P_{Loss} \tag{6}$$

$P_{Loss}$ = system total power loss.

There are two common approaches in EDP to include losses: power flow based and B-coefficient based. Power flow based incurs high convergence risk and time consuming thereby making its applications in real time scenario undesirable (Huang *et al.*, 2018). The transmission loss is expresses as a function of generator power using Loss Coefficients or the B-Coefficients. This is based on the assumption that the transmission loss is quadratic in the injected bus real power under normal operating conditions (Rahul *et al.*, 2014; Kaur *et al.*, 2015). The transmission line loss equation is given in (7). Equation 8 is a general expression that accounts for both the linear and constant terms referred to as Kron's Loss formula.

$$P_{Loss} = \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} P_i B_{ij} P_j \tag{7}$$

$$P_{Loss} = \sum_{i=1}^{N_g} \sum_{j=1}^{Ng} P_i B_{ij} P_j + \sum_{i=1}^{Ng} B_{oi} + B_{oo} \tag{8}$$

where;

$B_{ij}$ = ith component of loss coefficient square matrix

$B_{0i}$ = ith component of the loss coefficient vector

$B_{00}$ = loss coefficient constant.

### 2.3 Valve-Point Loading Effect

Generally, practical and more accurate economic dispatch solution can be obtained through the VPE. When the valve-point loading effects are neglected, the objective cost function (equation 1) is considered as quadratic (Jadoun *et al.*, 2014). The construction of large turbine generators is usually in such a way that they are provided with numerous fuel admission valves operated sequentially to meet demand of increased generation. Valve-Point loading presents ripples in the heat rate curves of generators and consequently introduces non-convexity in the price function of generators (Mara, 2017). Valve-point loading effect is modeled as sinusoidal function in the cost function, with equation 9 giving the non-convex EDP objective cost function considering valve-point effects.

$$C_i(P_i) = a_i + b_i P_i + c_i P_i^2 + \left| e_i \sin\left( f_i \left( P_i^{\min} - P_i \right) \right) \right| \tag{9}$$

Where; $e_i$ *and* $f_i =$ cost coefficients of generator i reflecting valve-point effect.

### 2.4 Particle Swarm Optimization

The PSO technique is population based method, inspired biologically, which was proposed and evolved in 1995 by Kennedy and Ebehart (Al-Nahhal *et al.*, 2019). The social behaviour of birds flocking and fish swarming for foods formed the basis of PSO. When birds search for foods, each bird tells every other bird the best source of food it has found, assuming there is no leadership, and attempts to adjust its path considering its best position and best position seen by the whole flock. PSO has the following advantages according to Lee and Park (2006):

(i) It is less sensitive to the objective function nature unlike the deterministic and some other heuristic methods.
(ii) It has a smaller parameters number which has less impacts on the quality of solutions.
(iii) It is less dependent on the initial conditions making the convergence algorithm robust.
(iv) It generates high quality solution and has stable convergence characteristics.

An individual bird in PSO is called a particle which has unique position and velocity in an n-dimensional search space. Let x and v represent the objective and velocity of a particle respectively. The position, x, denotes the objective variable in the optimization problem and velocity, represents the step size the particle will move in the succeeding iteration (ManojKumar and Singh, 2018). The ith particle position and its velocity are represented in the n-dimensional search expanse as in equation 10 and 11.

$$x_i = \left( x_{i1}, x_{i2}, \ldots, x_{in} \right) \tag{10}$$

$$v_i = \left( v_{i1}, v_{i2}, \ldots, v_{in} \right) \tag{11}$$

All particle retains a reminiscence of best position established so far and also the best position to date found by all particles in the flock represented as pbest and gbest respectively in the n-dimensional search space and are given in equations 12 and 13. The i$^{th}$ particle's velocity is upgraded using the equation 14 while the position is improved as given by the equation 15.

$$pbest_i = \left( pbset_{i1}, pbest_{i2}, \ldots, pbest_{in} \right) \tag{12}$$

$$gbest_i = \left( gbset_{i1}, gbest_{i2}, \ldots, gbest_{in} \right) \tag{13}$$

$$V_{in}^{j+1} = w v_{in}^{j} + c_1 r_1 \left( pbest_{in}^{j} - x_{in}^{j} \right) + c_2 r_2 \left( gbest_{n}^{j} - x_{in}^{j} \right) \tag{14}$$

$$x_{in}^{j+1} = x_{in}^{j} + V_{in}^{j+1} \tag{15}$$

where; $v_{in}^{j+1}$ = updated i[th] particle's velocity in n-dimensional space

w = inertial weight factor

$v_{in}^{j}$ = i[th] particle's velocity at iteration j

$c_1, c_2$ = acceleration coefficients

$r_1, r_2$ = random numbers [0,1]

$x_{in}^{j+1}$ = updated position of i[th] particle in n-dimensional space

$x_{in}^{j}$ = position of i[th] particle at iteration j

The inertial weight factor, w, function is to improve convergence speed rate of the PSO algorithm according to declining inear function. Inertial weight factor is found using equation 16 and its best range is between 0.4 and 0.9. The flowchart for the PSO algorithm is given in Figure 1.

$$w = w_{\max} - \left( \frac{w_{\max} - w_{\min}}{iter_{\max}} \right) iter \qquad (16)$$

Where;

$w_{\min}$ = Weighting factor minimum value

$w_{\max}$ = Weighting factor maximum value

iter = Current iteration

$iter_{\max}$ = Maximum number of iterations

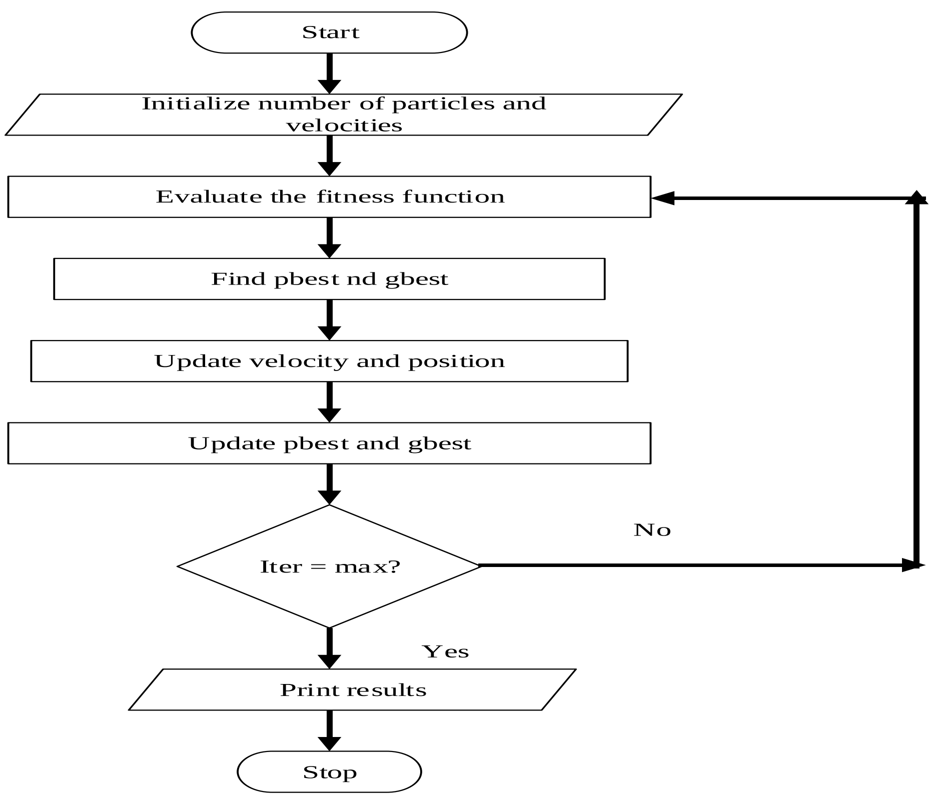


**Figure 1:** Particle Swarm Optimization Algorithm

### 2.5 Nigerian Power System

Figure 2 expresses the single line diagram of the power system. The system has four thermal stations and three hydro-generating stations. The characteristics and the limits of the thermal power plants are given in Table 1. A MATLAB program was developed to solve the EDP of the Nigerian 31-bus 7-generators power system. Like in the works compared, the hydro plants contributions to the load demanded were predetermined while the thermal plants power schedule were determined. The PSO parameters were assumed as follows:

Population size = 100
Maximum number of iterations = 1000
Penalty factor = 1e4
$C_1 = C_2 = 2.05$
$w_{max} = 0.9$
$w_{min} = 0.4$

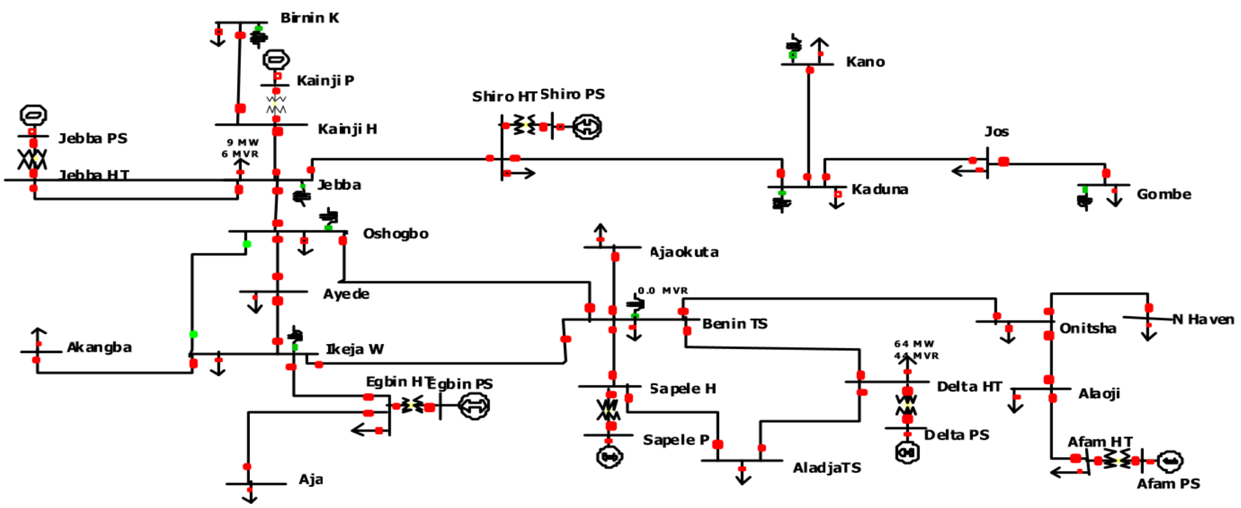


**Figure 2:** Single line diagram of Nigerian 330kV 31-bus grid systems (Olakunle and Folly, 2015)

Table 1: Plant Characteristics and Limits of Nigerian Thermal Stations (Olakunle and Folly, 2015)

| Units | A | B | c | E | f | $P_{min}$ | $P_{max}$ |
|---|---|---|---|---|---|---|---|
| Egbin | 12787 | 13.1 | 0.031 | 850 | 0.094 | 275 | 1100 |
| Sapele | 6929 | 7.84 | 0.13 | 600 | 0.052 | 137.5 | 550 |
| Delta | 525.74 | 6.13 | 0.092 | 260 | 0.028 | 75 | 300 |
| Afam | 1998 | 56 | 0.092 | 450 | 0.048 | 135 | 540 |

## 3. RESULTS AND DISCUSSION

The results of ED solution on the Nigerian power system using PSO are shown in Table 2. The contributions of each generator to the total load demanded and losses were 1065 MW for Eghin thermal station, 291.3 MW for Sapele, 37.7 MW for Delta, 177.6 MW for Afam and 490 MW, 350 MW, 450 MW respectively for Shiror, Kainji and Jebba hydro stations. The total power generated is 2861.7 MW which is a sum of the total power demand of 2823.1 MW and total power loss of 38.55 MW. The cost of generation using PSO was given as 109,410 $/hr.

Table 3 exhibits the juxtaposition of PSO results with results of previous works obtained from Olakunle and Folly (2015). From the Table, the minimum cost of production when both losses and VPE were considered is 113,410 $/hour for Micro-GA method (MGA), 112,736 $/hour for GA method, 110,324 $/hour for Multi-population GA (MPGA) and 109,610 $/hour for PSO.

It could be observed that the best result from the literature was produced by MPGA and gave the total minimized cost of generation of 110,324 $/hour. The result of total cost of 109,410 $/hour for PSO shows that PSO gives a cost lower than the best cost from literatures and this translates to the fact PSO gave the best performance.

**Table 2:** EDP Solution of Nigerian Power System using PSO

| Units | PSO |
|---|---|
| Egbin (MW) | 1065.0000 |
| Sapele (MW) | 291.3000 |
| Delta (MW) | 37.7000 |
| Afam (MW) | 177.6000 |
| Shiroro (MW) | 490.0000 |
| Kainji (MW) | 350.0000 |
| Jebba (MW) | 450.0000 |
| Total Power Generated (MW) | 2861.70 |
| Power Demand (MW) | 2823.1 |
| Power Loss (MW) | 38.55 |
| Cost ($/hour) | 109,410 |

**Table 3:** EDP Solution of Nigerian Power System Comparison

| Units | MGA | GA | MPGA | PSO |
|---|---|---|---|---|
| Egbin (MW) | 838.3900 | 814.5600 | 817.4700 | 1065.0000 |
| Sapele (MW) | 345.4600 | 457.7900 | 451.1300 | 291.3000 |
| Delta (MW) | 88.4800 | 89.5100 | 89.8200 | 37.7000 |
| Afam (MW) | 300.4600 | 212.8200 | 215.6200 | 177.6000 |
| Shiroro (MW) | 490.0000 | 490.0000 | 490.0000 | 490.0000 |
| Kainji (MW) | 350.0000 | 350.0000 | 350.0000 | 350.0000 |
| Jebba (MW) | 450.0000 | 450.0000 | 450.0000 | 450.0000 |
| Total Power Generated (MW) | 2862.79 | 2862.68 | 2864.04 | 2861.70 |
| Power Demand (MW) | 2823.1 | 2823.1 | 2823.1 | 2823.1 |
| Power Loss (MW) | 39.69 | 41.58 | 40.94 | 38.55 |
| Cost ($/hour) | 113,410 | 112,736 | 110,324 | 109,410 |

## 4. CONCLUSIONS

This work applied PSO to solve the EDP of the Nigerian power system considering the VPE on the system. The PSO result was weighed-up with the results of previous works on the same power system using three different variants of GA (traditional GA, MGA and MPGA). The result of PSO gave the best minimized cost of generation. It can be surmised that PSO algorithm is an efficient tool to perform EDP solution of large power systems.

## References

Abanihi, V. K. and Ovabor, K. O. (2019). Economic Load Dispatch of Nigeria Integrated High Voltage Generation and Transmission Grid using Bat Algorithm. *Nigerian Journal of Technology*, 38(3): 680 – 687.

Ade-Ikuesan, O. O., Olabode, O. E., Okakwu, I. K. and Okelola, M. O. (2019). Sate-of-the-Art Approach to Economic Load Dispatch of Nigerian Hydro-Thermal Electric Power System: A Review. *Journal of Science and Technology Research*, 1(2): 87 – 99.

Ajenikoko, G. A., Olabode, O. E. and Lawal, A. E. (2018). Application of Firefly Optimization Technique for Solving Convex Economic Load Dispatch of Generation in Nigerian 330kV, 24-Bus Grid System. *European Journal of Engineering Research and Science*, 3(5): 77 – 81.

Al-Farsi, F. N., Albadi, M. H., Hosseinzadeh, N. and Badi, A. H. (2015). Economic Dispatch in Power Systems, *Proceedings of 8th IEEE GCC Conference and Exhibition, Muscat, Oman, 1 – 4, February, 2015.*

Al-Nahhal, R., Naiem, A. F. and Hegazy, Y. G. (2019), Economic Load Dispatch Problem using Particle Swarm Optimization Technique considering Wind Power Penetration, *2019 International Conference on Smart Energy and Technologies, Porto, Portugal, 2019, Pp. 1 – 6.*

Amos, C., Musa, S. Y. and Thuku, I. T. (2017). Particle Swarm Optimization Based Economic Load Dispatch of Nigeria Hydrothermal Considering Hydro Cost Functions. *International Journal of Engineering Science and Computing*, 7(8): 14689 – 14696.

Bakare, G. A., Aliyu, U. O., Vanagamoorthy, G. K. and Shu'aibu, Y. K. (2005). Genetic Algorithm Based Economic Dispatch with Application to Coordination of Nigerian Thermal Power Plants. *IEEE Power Engineering Society Meeting, 2005*, 1: 551 – 556.

Chakrabarti, A. and Hadler, S. (2010). Power System Analysis: Operation and Control', 3rd Edition, PHI Learning Pvt. Ltd. New Delhi, India.

Frank, S., Steponavice, I. and Robenack, S. (2012). Optimal Power Flow: A Bibliographic Survey I, Formulations and Deterministic Methods. *Energy Systems*, 3: 221 – 258.

Haruna, Y. S., Bakare, G. A. and Aliyu, U. O. (2004). Comparison of Economic Load Dispatch using Micro-Genetic Algorithm and other Optimization Techniques. *Nigerian Journal of Tropical Engineering,* 5(1 and 2): 52 – 57.

Haruna, Y. S., Yisah, Y. A., Bakare, G. A., Haruna, M. S. and Oodo, S. O. (2017). Optimal Economic Load Dispatch of the Nigerian Thermal Power Stations using Particle Swarm Optimization. *The International Journal of Engineering and Science*, 6(1): 17 – 23.

Haruna, Y. S., Idris, S., Bakare, G. A. and Abu, A. U. (2018). Comparative Analysis of the Economic Load Dispatch Problem of the Nigerian Thermal Power Stations. *Global Science Journals*, 6(4): 243 – 251.

Huang, W., Yao, K., Wang, F., Zhu, C., Chang, Y., Lee, Y. and Ho, Y. (2018). Derivation and Application of a New Transmission Loss Formula for Power System Economic Dispatch, *Energies* 11(417): 1 – 19.

Ibe, A. O., Uchejim, E. E. and Esobinenwu, C. S. (2014). Optimal Load Dispatch in the South/South Zone of Nigeria Power System by Means of Particle Swarm. *International Journal of Scientific and Engineering Research*, 5(11): 128 – 139.

Jadoun, V. K., Gupta, N., Niazi, K.R., and Sivainkar, A. (2014). Nonconvex Economic Dispatch using Particle Swarm Optimization with Time Varying Operators. *Advances in Electrical Engineering*, 2014: 1 – 13.

Karakonstantis, I. and Vlachos, A. (2015). Ant Colony Optimization for Continuous Domain Applied to Emission Generation and Economic Dispatch Problem. *Journal of Information and Optimization Science*, 36: 23 – 42.

Kaur, N., Maninder, A. and Singh, I. (2015). Economic Dispatch Scheduling using Classical and Newton-Raphson Methods. *International Journal of Engineering and Management Research*, 5(3): 711 – 716.

Lavaei, J. and Low, S. (2012). Zero Duality Gap in Optimal Power Flow Problem. *IEEE Transactions on Power Systems*, 27(1): 92 – 107.

Lee, K. Y. and Park, J. (2006). Application of Particle Swarm Optimization to Economic Dispatch Problem: Advantages and Disadvantages, 2006 IEEE PES Power System Conference and Exposition, Atlanta, GA, 2006: 188 – 192.

Liu, D. and Cai, Y. (2005). Taguchi Method for Solving the Economic Dispatch Problem with Nonsmooth Cost Functions. *IEEE Transactions on Power Systems,* 20(4): 2006 – 2014.

Mara, R. J. (2017). A Dispatching of Load for Conventional Generator by using a Particle Swarm Optimization Technique. *International Journal for Research in Applied Sciences and Engineering Technology*, 5(X): 1111 – 1118.

ManojKumar, T. and Singh, N. A. (2018). Solution of Environmental/Economic Power Dispatch Problem using Particle Swarm Optimization. *2018 International Conference on Control, Power Communication and Computing Technologies*, 347 – 351.

Mehta, S. and Singh, H. (2018). Solution to Economic Load Dispatch with Valve Point Loading Effect using Hybrid Whale Optimization Algorithm. *International Journal of Computer Applications,* 180(11): 39 – 47.

Nwohu, M. N. and Osaremwinda, O. P. (2017). 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,* 3(1): 20 – 29.

Okozi, S. O., Ogbonna, G. C., Olubiwe, M. and Ezugwu, E. O. (2019). Solution to the Economic Dispatch Problem of the Nigerian Power System using Genetic Algorithm. *Nigerian Journal of Technology,* 38(4): 1036 – 1047.

Olakunle, A. O., Bakare, G. A. and Aliyu, U. O. (2014). Short-Term Economic Dispatch of Nigerian Thermal Power Plants Based on Differential Evolution Approach. *International Journal of Scientific and Engineering Research*, 5(3): 1 – 6.

Olakunle, A. O. and Folly, K. A. (2015). Economic Load Dispatch of Power System using Genetic Algorithms with Valve-Point Effect. *Advances in Swarm and Computational Intelligence Lecture Notes in Computer Science*, 9140: 276 – 284.

Oluwadare, S. A., Iwasokan, G. B., Olabode, O., Olusi, O. and Akinmorin, A. E. (2016). Genetic Algorithm-Based Cost Optimization Model for Power Economic Dispatch. *British Journal of Applied Science and Technology,* 15(6): 1 – 10.

Orike, S. and Corne, D. W. (2013). Constrained Elitist Genetic Algorithm for Economic Load Dispatch: Case Study on Nigerian Power System. *International Journal of Computer Applications*, 76(15): 27 – 33.

Pandya, K. S. and Joshi, S. K. (2008). A Survey of Optimal Power Flow Methods. *Journal of Theoretical and Applied Information Technology*, 4(5): 450 – 458.

Rahul, D., Nikita, G. and Harsha, S. (2014), Economic Load Dispatch Problem and Matlab Programming of Different Methods, *International Conference of Advanced Research and Innovation (ICARI – 2014),* Pp. 202 – 207.

Raju, P., Vaisakh, K. and Raju, S. (2009). An IPM-EPSO Based Hybrid Method for Securitu Enhancement using SSSC. *International Journal of Recent Trends in Engineering,* 2(5): 208 – 212.

Roy, P., Roy, P. and Chakrabarti, A. (2013). Modified Shuffled Frog Leaping Algorithm with Genetic Algorithm Crossover for Solving Economic Load Dispatch Problem with Valve-Point Effects. *Applied Soft Computing.*

Shalini, S. P., and Lakshmi, K. (2014). Solving Environmental Economic Dispatch Problem with Lagrangian Relaxation Method. *International Journal of Electronic and Electrical Engineering,* 7(1): 9 – 20.

Shrivastava, A. and Siddiqui, H. (2014). A Simulation Analysis of Optimal Power Flow Using Differential Evolution for IEEE-30 Bus System. *International Journal of Recent Development in Engineering and Technology,* 2(3): 50 – 57.

Tchapda, G. Y. N., Wang, Z. and Sun, Y. (2017). Application of Improved Particle Swarm Optimization in Economic Dispatch of Power System. *10th International Symposium on Computational Intelligence and Design, China, 9 – 10 December, 2017*, 2: *500 – 503.*

Thanathip, S. (2004). Economic Dispatch by Ant Colony Search Algorithm. *Proceedings of IEEE Conference on Cybernetics and Intelligent Systems,* Singapore 1 -3 December 2004. Pp. 416 – 421.

Thukral, D. J. and Rai, H. M. (2012). Ant Colony Optimization: A New Approach for Economic Load Dispatch. *International Journal of Research in Engineering and Applied Sciences*, 2(11): 59 – 69.

Tijani, M. A., Adepoju, G. A., Hamzat, K. A. and Sanusi, M. A. (2019). A Review of Optimization Approach to Power Flow Tracing in a Deregulated Power System. *Arid Zone Journal of Engineering, Technology and Environment,* 15(2): 435- 448.

Zou, D., Li, S., Wang, G., Li, Z. and Ouyang, H. (2016). An Improved Differential Evolution Algorithm for the Economic Load Dispatch Problem with or without Valve-Point Effects. *Applied Energy,* 181(2016): 375 – 390.