A New Meta Heuristic Evolutionary Programming (NMEP) in Optimizing Economic Energy Dispatch

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***Abstract*— Economic and efficient energy dispatch management is compulsory to address the growth in energy demand within a limited energy resources whereas maintaining the secure power system operation. Many researches were conducted to study and develop new tools to overcome the problems during Economic Dispatch (ED) implementation. Mainly, ED problems considered on the total cost minimization at the same time the obligation of social attentions have inclined in reducing the energy conservation and pollution emission produced by power plants. As a result, a new algorithm was developed not only in minimizing the total generation cost but with an addition on minimum total emission and less system losses as the individual objective function in ED. The proposed optimization algorithm, namely New Meta-Heuristic Evolutionary Programming (NMEP) algorithm is followed to Meta-Heuristic Evolutionary Programming (Meta-EP) approach with some modification where the cloning process embedded as a significant progress during the implementation. This approach is utilized specifically to solve the single objective function which considered as minimum total generation cost, less sum of polluted emission and also a reduced amount in power system losses. The comparison evaluation between the original Meta-EP is conducted in order to show the effectiveness of the identified NMEP to overcome the ED issues. As a result, the best answer of the corresponding individual objective functions produced through NMEP approach. The simulation is tested on standard IEEE 26 bus system using the MATLAB software programming.**

***Keywords*— Meta-EP; Economic dispatch; Evolutionary algorithm.**

I. Introduction

Lately, the rises in energy demand and lack of energy resources required to efficient and secured dispatch. Thus, the power system optimizations become a vital study for optimal power operation to guarantee smooth and sustainable load demand. Generally, the main objective of load dispatch is to minimize the total generation cost with the limitation of operational parameters. However, in today's environment the requirement in ED problem not only to schedule the power generation at least cost but also other performance factors need to be optimized in power system operation. Therefore, the reduction in pollution as a result of electrical power generation caused the minimization in emission must be added to be another objective function of ED problem. Since the ED problems are now getting complicated due to large number of variables working together with undefined parameters thus the mathematical solution involved with non-differentiable and resulted in nonlinear solutions. For that reason, many studies have been focused to overcome the complicated optimization issue in power system operation.

From the last 20 years, most optimization techniques were classified into three different categories which are conventional methods, intelligent search and fuzzy set application. The conventional methods include Linear Programming (LP), Non Linear Programming (NLP) and Mix Integer Non Linear Programming (MINLP) [1]. While, the Gradient based conventional methods like a Newton Methods (NM), LP and Quadratic Programming (QP) have been reported may resulted to poor solutions solving problem that are non-convex, non-continuous and having highly non-linear solutions. As an alternative, the meta-heuristics intelligent search methods were presented such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Evolutionary Programming (EP), Simulated Annealing (SA) and Ant Colony Optimization (ACO) focused to optimize the selected single objective function by providing global optimal solutions [2]. This meta-heuristic method was first declared by Glover in 1986 [3]. Natural biological systems have evolved over millions of years and the efficiency of meta-heuristic algorithms can be trusted because of a mimic on the best natural features. The main advantage in meta-heuristic algorithm is exploring the space efficiently without being sensitive to the size of the search space [4]. For that reason, the meta-heuristics are often employed to solve complex problems which need for faster, robust algorithms and explore larger space solutions [4]. In addition, a simple of design and flexible implementation are also advantageous of these algorithms. This approach has become a vital tool of optimization algorithm which is divided into acceleration and diversification characteristics. It is ability to guarantee the local optimal solution is referred to acceleration whereas searching more spaces raised from diversification behavior [5]. Later, new technique which based on immunity algorithm namely the Artificial Immune System (AIS) has been applied in getting the minimum total generation cost objective function for ED problem. However, Evolutionary Algorithms (EAs) also became popular methods of artificial intelligence and have been successfully applied on several of optimization problems. There are various types of EAs optimization techniques called as Evolutionary Programming (EP), Genetic Programming (GP), Evolution Strategies (ES), and Genetic Algorithm (GA) [6]. The well-known algorithm in EA approach was mentioned to be EP definitely in solving optimization problem in power system [7]. In their studies, the minimum whole generation cost and power system losses of ED as the most important optimization task in power system operation [6].

The original EP was introduced by Fogel et al in 1960 [1]. The EP is exactly the finite state machines of evolution in answering prediction task. From the adaptation of uniform random Gaussian mutation on the corresponding alphabet, the state is created of the transition table. The main engine operators of the process are called mutation and selection. Therefore, the stochastic tournament is employed to produce the best generation in the selection process [8]. The best performance solution is determined to be the winner for each selected objective functions.

This research developed a New Meta Heuristics Evolutionary Programming (NMEP) inspired from original EP algorithm with adoption of cloning process next to mutation progression. The approach is deployed to obtain the best answer for each objective function of ED problems considered as minimum total generation cost, less emission polluted and the least system losses respectively. Thoroughly, the experimental were conducted together with the original Meta-EP in order to evaluate the best performance method. The total generation cost operation at least amount, minimum emission produced by generation plants and less entire system losses will be the best results. The implementation was tested on standard IEEE 26 bus system using the MATLAB software programming.

II. ECONOMIC DISPATCH

A. Objective Functions

There are several approaches to solve the environmental economic dispatch issues. One of the strategies may involve all the objectives considered which are minimizing total generation cost, minimizing total emission or total system losses minimization. These objectives are considered as a single objective function individually [9]. Each objective function is formulated as in the following sections. The total system loss, total emission and total generation cost formula for optimization algorithm are shown below [7].

(a) Total Generation Cost Minimization

Principally, the important objective function of ED is identified to be total generation cost minimization. This single objective function is presented in mathematical formulation as in Equation (1) [7].

$$C_{Total} = \sum_{i=1}^{Ng} C_i\,(Pg_i) \qquad \text{dollar per hour (\$/h)} \qquad (1)$$
$$C_i\,(Pg_i) = a_i + b_i Pg_i + c_i {Pg_i}^2$$

where, $C_i\,(Pg_i)$ is the cost of generation for unit i, Pg_i is the power generated by unit i, a_i, b_i, c_i is the cost coefficient for unit i, and C_{Total} is the sum function for each generating unit Ng.

(b) Total Emission Minimization:

The next essential objective function is total emission reduction which dispersed by thermal generator as given by Equation (2).

$$E_{Total} = \sum_{i=1}^{N_G} (\gamma_i {P_{g_i}}^2 + \beta_i P_i + \alpha_i) * (10^{-2}) + \varepsilon_i \, exp(\lambda_i P_{g_i}) \qquad ton/h \qquad (2)$$

where, E_{Total} is the sum function for each generating emission unit Ng, $\gamma_i, \beta_i, \alpha_i, \varepsilon_i, \lambda_i$ is the emission coefficient for unit i, and Pg_i is the power generated by unit i.

(c) Total System Loss Minimization:

Another significant objective function is to obtain the minimum entire losses during power system operation. This objective function is formulated as Equation (3).

$$T_{loss} = \sum_{i=1}^{Ng} Pg_i - P_{load} \qquad Watt\,(W) \qquad (3)$$

where, T_{loss} is the sum of losses in system demand, Pg_i is the power generated by unit i, and P_{load} is the sum of load in system demand.

B. Constraints

In obtaining the total generation cost minimization hence the following equality and inequality operational constraints must be under their limitations [10].

(a) Equality constraint formula:

$$\sum_{i=1}^{Ng} P_{g_i} = P_{load} + T_{loss} \qquad (4)$$

where, P_{load} is system load demand and T_{loss} is total system losses.

(b) Inequality constraint formula:

$$P_{min} \leq P_{g_i} \leq P_{max} \qquad (5)$$

where, P_{min} is the minimum real power generation of unit *i* and P_{max} is the maximum real power generation of unit *i*.

III. METHODOLOGY

A New Meta Heuristic Evolutionary Programming Algorithm (NMEP)

Basically, the NMEP is followed the original Meta-EP algorithm progression but with some addition of cloning process after the Gaussian mutation operation as the improvement. Mainly, this approach is applied as optimization tool to minimize the total generation cost, emission generated and system losses individually. This work is conducted using MATLAB simulation process on standard IEEE 26 bus system.

All 6 generator units in the system are considered as the control variables to be optimized in order to achieve the minimum single objective functions respectively. Generally, the NMEP was involved with several important processes known as initialization, fitness, mutation, cloning and selection process. The Newton Raphson load flow method is executed to calculate the objective functions that applied in the certain process in simulation to gain the best result. Figure 1 represents the flow chart for all process involved during NMEP algorithm implementation. The following section will explained on the main processes incorporated.

(a) Step 1: Initialization

The initialization process in NMEP was conducted by generating an initial population using a uniformly distributed random number generation. In MATLAB programming, the rand function generates a random numbers whose elements are uniformly distributed in the interval (0 to 1). In order to determine the minimum total cost, less emissions and minimum system losses thus the random numbers represent the Real Power output (Pg) of committed generating units Pg1, Pg2, Pg3, Pg4, Pg5 and Pg26 as the variables to be optimized. While, the number of population is set to 20 random numbers with some constraints values need to be satisfied. According to previous research, the minimum voltage must be within 0.9 p.u to 1.05 p.u. during system operation to ensure secured environment [11].

(b) Step 2: Evaluation of the fitness value of each population

The selection of the proper fitness function is a key for the optimization problem. Fitness function assigns a significance value to each individual of the population depending on how well the solution performs the desired functions and satisfied the given constraints. It will decide which individuals of the population survive for the next generation. The fitness values of individuals in a given population are used to execute the evolution process. The fitness values for each objective function are calculated according to Equations (1) to (3) in Section 2.

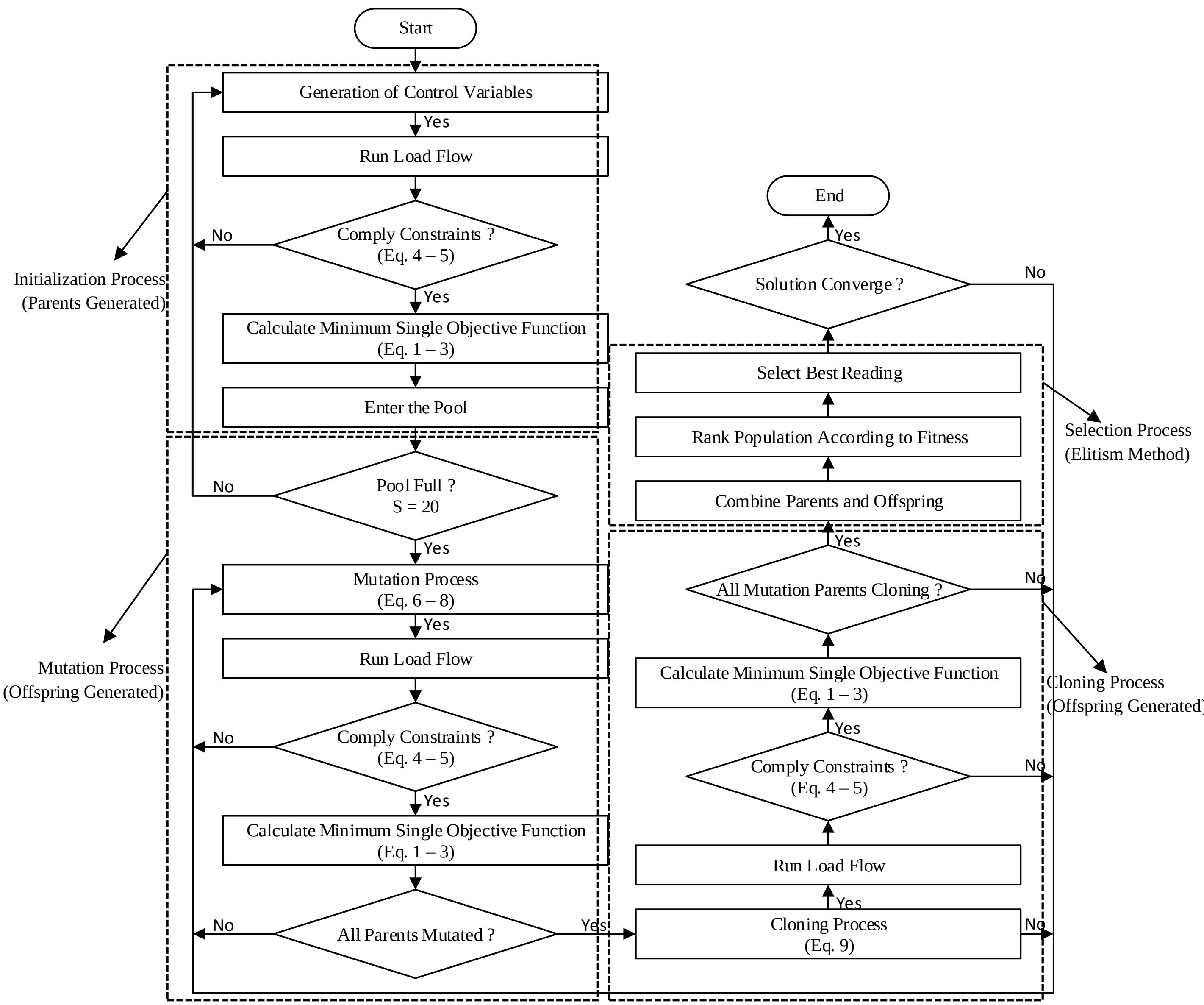

Figure 1: The flow Chart of a New Meta Heuristic Evolutionary Programming (NMEP) Algorithm.

(c) Step 3: Mutation process

A new generation is formed through mutating the initial existing population using the mutation operator. Mutation is the variant operator used for generating the new generation namely offspring from each parent according to Equation (6), (7) and (8). The fitness of the offspring was also calculated as in Step 2.

$$\eta'_{i,j} = \eta_{i,j} \exp(\tau' N(0,1) + \tau N_j(0,1)) \quad (6)$$

$$L'_{i,j} = L_{i,j} + \eta'_{i,j}(N_j(0,1)) \quad (7)$$

$$L'_{oi,j} = L_{oi,j} + \eta'_{i,j}(N_j(0,1)) \quad (8)$$

where:

$$\tau = \sqrt{\frac{1}{\sqrt{2n}}}$$

$$\tau' = \frac{1}{\sqrt{2n}}$$

L_i and L_{oi}, $\eta_{i,j}$ and $\eta'_{i,j}$ is i^{th} components of the respective vectors. N(0,1) is a normally distribution one dimensional random number with mean 0 and 1. $N_j(0,1)$ indicates the new random number for each value of j.

(d) Step 4: Cloning

The offspring is duplicated to produce more number of assigned fitness to be ranked and elected. The mathematical formulation in equation (9) represents the cloning process involved in NMEP algorithm.

$$Clone = repmat\,(A, [a, b]) \quad (9)$$

where, A is fitness to be cloned, [a] is the clone the row of fitness and [b] is the clone the column of fitness.

(e) Step 5: Selection process

The offspring generated from the cloning process were combined with the parents to undergo the selection process. The selection process involved with the individual is to compete with other randomly selected individuals and the winning criteria was referred to the fitness values or also known as the tournament scheme. For each comparison the individual that obtained the most numbers of wins will be selected for the new generation. The competition approach was that the fittest individuals will have a greater chance to survive, while weaker individuals will be eliminated. Over this, the population evolves towards the global solution.

(f) Step 6: Convergence test

This practice is to agree the stopping criteria of the optimization process. The convergence criterion is specified by the difference between the maximum and minimum fitness to be less than 0.001. If the convergence condition is not satisfied, the mutation, cloning and selection processes will be repeated again until convergence criterion is met.

$$maximum_{\text{fitness}} - minimum_{\text{fitness}} \leq 0.0001$$

IV. Result And Discussion

Initially, the committed generating units Pg2, Pg3, Pg4, Pg5 and Pg26 selected as the control variables in standard IEEE 26 bus systems produced the minimum total cost, entire emission and system losses. Table 1 display the setting cost, MV limit and emission coefficients are used throughout the simulation process for up to 13 times for 100 iterations in order to get the best solutions. While, the optimized generating units for both NMEP and Meta-EP obtained the readings has been recorded in Table 2. Figure 2 plots the graphic visual of the outputs obtained from these two optimization techniques. The graph illustrates that the lowest total generation cost of 15444.10 dollar/hour was achieved by the proposed NMEP approach. As a result, the best answer was achieved by the NMEP technique which offers to spend the less total cost at about 9259.2 dollar/hour in a month and 112653.6 dollar/hour for the whole year, than Meta-EP.

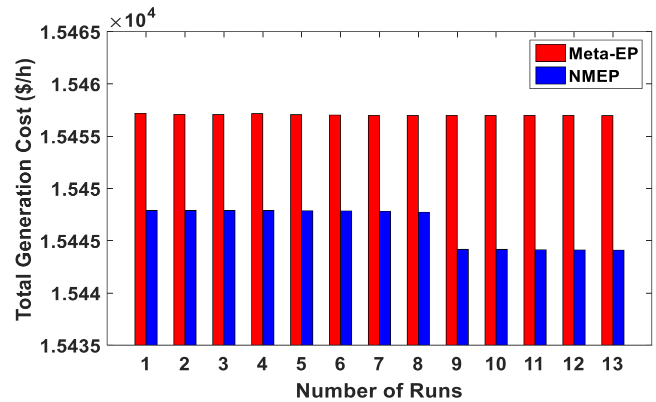

Figure 2: The comparison graph of total generation cost against number of runs between Meta-EP and NMEP algorithm.

The next objective function tested was the minimization of total emission using the same model NMEP approach. The simulation of NMEP also was repeated 13 times in order to observe the consistency of the results. The graph in Figure 3 highlights the lowest emissions of 14335.2 ton/month whilst 174411.6 ton/year using this identified method as compared with Meta-EP implementation with faster time requirement.

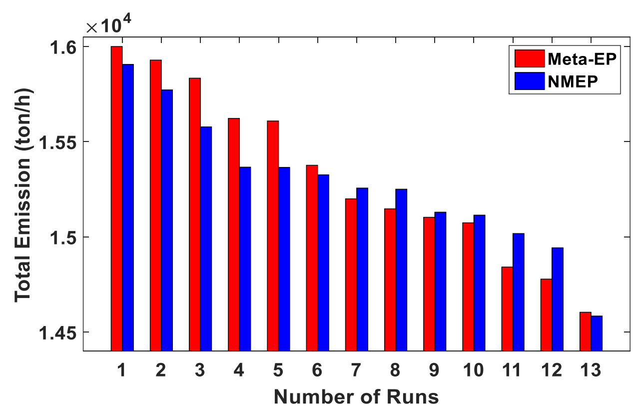

Figure 3: The comparison graph of total emission against number of runs between Meta-EP and NMEP algorithm

Table 1
The parameters used to produce the result for NMEP and Meta-EP algorithm

No. of Generator	Cost Coefficients			MV Limit		Emission coefficient α	β	γ	ε	λ
1	240	7.0	0.0070	100	500	4.091	-5.543	6.490	2.0e-4	2.857
2	200	10.0	0.0095	50	200	2.543	-6.047	5.638	5.0e-4	3.333
3	220	8.5	0.0090	80	300	4.258	-5.094	4.586	1.0e-6	8.000
4	200	11.0	0.0090	50	150	5.326	-3.550	3.380	2.0e-3	2.000
5	220	10.5	0.0080	50	200	4.258	-5.094	4.586	1.0e-6	8.000
26	190	12.0	0.0075	50	120	6.131	-5.555	5.151	1.0e-5	6.667

Table 2
The results obtained from NMEP and Meta-EP algorithm based on standard IEEE 26 bus system

	Meta-EP			NMEP	
Total System Loss (MW)	Total Generation Cost ($/h)	Total Emission (ton/h)	Total System Loss (MW)	Total Generation Cost ($/h)	Total Emission (ton/h)
13.5177	15457.18	15999.97	12.8117	15447.89	15906.17
13.5108	15457.07	15928.64	12.8112	15447.89	15772.14
13.5096	15457.06	15833.7	12.8099	15447.87	15577.95
13.5093	15457.15	15622.33	12.8098	15447.87	15366.42
13.5092	15457.05	15608.79	12.8087	15447.85	15365.09
13.5065	15457.01	15376.31	12.8082	15447.84	15326.18
13.5043	15456.98	15200.18	12.8067	15447.82	15256.57
13.5045	15456.98	15147.63	12.8009	15447.73	15250.59
13.5043	15456.98	15103.1	12.5647	15444.17	15129.93
13.5043	15456.98	15074.24	12.5640	15444.16	15114.44
13.5042	15456.98	14841.91	12.5612	15444.12	15017.7
13.5043	15456.98	14778.54	12.5603	15444.11	14942.77
13.5029	**15456.96**	**14604.43**	**12.5597**	**15444.10**	**14584.52**
Average Time : 14.597660 seconds			**Average Time : 10.867040 seconds**		

The other important objective function which to reduce the total system loss also have been determined on the standard IEEE 26 bus power network. The new proposed NMEP is repeatedly executed 13 times under consistent setting parameters. The outputs as displayed in Figure 4 view the most excellent result among the 13 times execution. Throughout analysis, a minimum total loss was showed at 12.5597MW that 0.9432MW less than Meta-EP. Additionally, the less losses save about 21482.32 dollar per year as compared to Meta-EP method (if charge is 0.26cent for every kW/h).

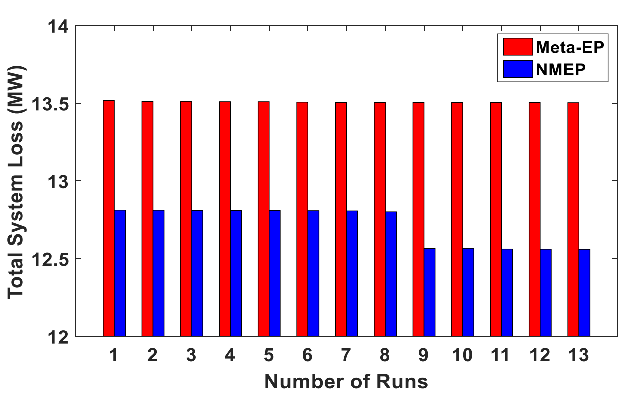

Figure 4: The comparison graph of total system loss against number of runs between Meta-EP and NMEP algorithm.

V. Conclusion

This study presented the development of new optimization technique and objective functions for solving Secured Environmental Economic Dispatch (SEED) problems in power system. The new optimization technique is called NMEP. NMEP is an improved technique resulting from the adaption cloning process applied at the original Meta-EP algorithm, which is inspired from AIS.

A secured load dispatch is compulsory since the rises in energy demand and inadequacy of energy resources. At the same time, the pressure from public awareness contributes to the requirement for reduction in toxic waste emissions produced by the power plants. Therefore, this research studied and developed an optimization technique namely the NMEP aimed to deliver the demand in an economical way without compromising on the well-being of the environment. For the reason, several significant objective functions were identified and implemented in the NMEP optimization technique in order to overcome the issues. Based on previous researches, the significant objective functions to be determined included the total operation costs, the pollutant emitted as a result of burning of fuel and the total system losses that evaluated individually. The results obtained from NMEP were compared with that obtained from Meta-EP. From the comparison, it was establish that NMEP performed better in terms of minimizing the single objective functions.

Acknowledgment

The research is financially supported by team of this project from Advance Digital Signal Processing Laboratory (ADSP Lab). Special thanks also go to the Faculty of Electrical Engineering of Universiti Teknikal Malaysia Melaka (UTeM) for giving the cooperation and funding to this research who make the research successful which are RAGS/1/2015/TK0/ FKE/03/B0094.Their support is gratefully acknowledged.

REFERENCES

[1] K. S. Lee and Z. W. Geem, "A New Meta-Heuristic Algorithm for Continuous Engineering Optimization: Harmony Search Theory and Practice. *Comput. Methods Appl. Mech. Eng.*, vol. 194, 2005, no. 36–38, pp. 3902–3933.

[2] Z. Zakaria, T. K. A. Rahman and E. E. Hassan, "Economic Load Dispatch via An Improved Bacterial Foraging Optimization," *in 2014 IEEE Int Power Engineering and Optimazation Conference*, pp. 380–385.

[3] I. Boussaïd, J. Lepagnot, and P. Siarry, "Information Sciences A Survey on Optimization Metaheuristics," vol. 237, pp. 82–117, 2013.

[4] H. Salimi, "Knowledge-Based Systems Stochastic Fractal Search : A Powerful Metaheuristic Algorithm," *Knowledge-Based Syst.*, vol. 75, pp. 1–18, 2015.

[5] K. Mahadevan, P. Kannan, and S. Kannan, "Particle Swarm Optimization for Economic Dispatch of Generating Units with Valve-Point Loading," *J. Energy Environ.*, vol. 4, 2005, pp. 49–61.

[6] P. Jamalbhai, V. Chinmay, Y. J. Vasim, P. Harshad, and K. Bhavsar, "Economic Load Dispatch of IEEE-26 Bus System with The Use of Ant Colony Optimization Technique," *Int.J.Sci.Res.Dev*., vol. 2, 2014, no. 03, pp. 1213–1217.

[7] E. E. Hassan, T. K. A. Rahman, Z. Zakaria, and N. Bahaman, "The Improved of BFOA for Ensuring The Sustainable Economic Dispatch,"*Applied Mechanics And Material*, 2015, vol. 785,2015, pp. 83–87.

[8] S. Bandyopadhyay and S. Saha, "Unsupervised Classifications: Similarity Measures, Classical and Methaheuristic Approches, and Application", 2013, pp 17-58.

[9] L. Wang and C. Singh, "Environmental / Economic Power Dispatch using A Fuzzified Multi-Objective Particle Swarm Optimization Algorithm," *Electric Power System Research*, vol. 77, pp. 1654–1664, 2007.

[10] T. Yalcinoz, "A multiobjective Optimization Method to Environmental Economic Dispatch," in *Int Journal Of Electrical Power and Energy System*, vol. 29, 2007, pp. 42–50.

[11] J. Hazra and a. K. Sinha, "Environmental Constrained Economic Dispatch using Bacteria Foraging Optimization," *2008 Jt. Int. Conf. Power Syst. Technol. POWERCON IEEE Power India Conf. POWERCON 2008*, 2008.