# A Hybrid MEP and AIS Algorithm for Energy Dispatch in Power System

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***Abstract*** **— Power system optimization has become essential mechanism in order to provide smooth and sustainable load demand due to rising energy demand and inadequacy of energy required for quality and secured dispatch. A well-coordinated and optimized power system operation supports in sustaining Economic Dispatch (ED) among users of power networks. This necessitates for researches in developing new tools to overcome ED problems. Therefore, this paper introduces the new algorithm as an alternative method to provide the best solution in solving the single objective function of ED problems. Based on original Meta Heuristic Evolutionary Programming (Meta-EP) method with a consideration on cloning process as in Artificial Immune System (AIS) algorithm together thus identified as New Meta Heuristic Evolutionary Programming algorithm (NMEP). In order to verify the effectiveness of the proposed method the comprehensive analysis were done with other two familiar optimizations method named Meta-EP and AIS. The results with NMEP algorithm represent the most outstanding amongst the three within less computational time. Thus, the NMEP algorithm is the vital optimization mechanism particularly for single objective ED problem on standard IEEE 26 bus system.**

***Keywords - Economic Dispatch; Meta Heuristic Evolutionary Programming; Artificial Immune System.***

## I. INTRODUCTION

Economic dispatch (ED) shows an important role in power system operation. The growth of load demand combined with insufficiency of energy resources thus requires the need for effective solutions of ED. The main task of ED is to allocate system load demand to each generation units so that the demand could be supplied economically [1]. Traditionally, the aim of ED in power system is to minimize the total generation cost by the committed generating units in order to supply the demand as well satisfying the operation constraints. However, the recent concern on the environmental issues has insisted that power utility companies not only to focus on minimizing the operation costs but also reducing the greenhouse gas emission as a result of the burning of fossil fuel.

Besides that, the rise in power demand worldwide has led to a large increase in numbers of generation plants, either thermal, hydro, nuclear or named renewable energy system through wind, solar and tidal energy [2]. Despite that, main portions of the generation mix uses fossil fuel as the main source for electrical energy generation. As a result of the burning of fuel, harmful gasses or also known as greenhouse gases such as sulphur dioxides ($SO_2$), nitrogen dioxides ($NO_2$) and carbon dioxide ($CO_2$) were released to the atmosphere. This has caused serious concern among the environmentalists since the major cause of climate change in this world is due to the release of these greenhouse gases. In order to reduce pollution as a result of electrical power generation, minimization on emission must be added to the objective function of ED which is generation cost minimization.

Power system operation particularly on ED are now getting more challenging due to large number of variables working together with uncertain parameters that make the mathematical solutions more complicated. Thus, the classical approaches include Linear Programming (LP), Non Linear Programming (NLP) and Mix Integer Non Linear Programming (MINLP) is no longer applicable to solve ED problems. As reported in [2], the Gradient based conventional methods such as Newton Methods and Quadratic Programming may result in poor solutions of solving non-convex, non-continuous and highly non-linear problems. As an alternative, new advanced optimization methods were introduced which exhibit some artificial intelligence behaviors like Simulated Annealing (SA), Evolutionary Programming (EP), Genetic Algorithm(GA) and Artificial Immune System (AIS). Despite several algorithm artificial intelligence being applied on ED problems, the most familiar algorithm is found to be EP [3]. The original Evolutionary Programming algorithm is founded by Lawrence J. Fogel in 1960 [4]. EP is involved with stochastic optimization strategy as in GA, but stresses the importance of performance association between fitness and offspring. Later, new improved methods on Evolutionary Programming algorithm is introduced by Glover in 1986 named as a Meta Heuristic algorithm using higher level language designed to provide better solution of optimization problems [5].

This paper proposes the improvement of the Meta-EP with merging of cloning process that are involved during AIS algorithm process. The identified optimization method is utilized to solve the individual objective function included minimum total cost, less emission and smallest system losses.

The simulations were executed on standard IEEE-26 bus system using MATLAB software programming.

## II. OBJECTIVE FUNCTION

Based upon previous research, it is found that the solution to ED problem depends on the objective function selection. Hence, the suitable objective function must be carefully selected insofar to acquire the beneficial from ED. Here, the NMEP optimization method is developed to ensure that energy demand by customers could be delivered at minimum generation cost. Concurrently, the emission polluted due to burning of full will be reduced without violating system constraints. The minimum total system loss during operation is also considered as single objective function. These individual objective functions are stated in mathematical formulation as followed [6].

### A. Total Generation Cost Minimization

Mainly, the objective function of ED is to minimize the total cost of generation. The equation (1) is applied to achieve optimization objective function which is a quadratic function.

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

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 second important objective function is to reduce total emission is dispersed by thermal generator that is given by equation (2).

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

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

The system loss is subsequent essential objective function is to minimize system losses in a transmission line using the following equation (3).

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

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.

### D. Constraints of Minimization

The total generation cost minimization following equality and inequality constraints in the process of producing the result.

*a)* Equality constraint formula:

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

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

*b)* Inequality constraint formula:

$$P_{min} \le P_{g_i} \le P_{max} \quad (5)$$

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. METHODOLGY

EP is one of the Evolutionary Algorithm strategies (EAs) and is one of an artificial intelligence optimization method. Basically, the whole process in EP algorithm is on the mechanics of natural selection involved the initialization, mutation, recombination and selection progression. However, the cloning process as comprised in AIS progression is placed next to Gaussian mutation process in Meta-EP and identified as NMEP algorithm. There are several important processes involved NMEP algorithm in resolving the ED problems that are presented in Figure 1.

Firstly, the initialization process of the NMEP algorithm was conducted by generating an initial population using a uniformly distributed random number generation in the interval (0 to1). At the same time, to determine the minimum total cost, less emissions and minimum system losses, hence the random numbers represent real power output, Pg of committed generating units as the variables to be optimized. The initial population number are generated to be at 20 populations to proceed the next process [7].

In the next progression, the fitness or also known as objective function is assigned but must satisfy the given constraints. It will decide which individuals of the population survive for the next generation.

During mutation process, a new population is formed from mutating the initial population using the mutation operator. The variation operator is applied in generating the new generation called as offspring from each parent in the initial population according to equation (6), (7) and (8).

$$\eta'_{i,j} = \eta_{i,j} \exp(\tau' N(0,1) + \tau N_j(0,1)) \quad (6)$$
$$L'_{i,j} = L_{i,j} + \eta'_{i,j}(N_j(0,1)) \quad (7)$$
$$L'_{oi,j} = L_{oi,j} + \eta'_{i,j}(N_j(0,1)) \quad (8)$$

Where,

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

Where, $L_i$ 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. $N_j(0,1)$ is indicates the new random number for each value of $j$.

Similarly, the fitness also is calculated for every offspring produced. The subsequent process employed the cloning process on the mutated offspring, which this process is not included in Meta-EP. The fitness is calculated again for all cloning offspring. The cloning according the equation (9).

$$Clone = repmat\ (A, [a,b]) \tag{9}$$

Where, *A* is fitness to be cloned, *a* is the clone the row of fitness and *b* is the clone the column of fitness.

The cloned offspring were then combined together with the parents to undergo the selection process. The selection process involved the individuals' competition and the winning criteria was referred to the fitness values or also called as tournament scheme. The competition approach was that the fittest individuals will have a higher chance to survive whilst weaker individuals will be eliminated.

The final phase is to determine the stopping criteria of the optimisation process. The convergence criterion is indicated by the difference between the maximum and minimum fitness to be less than 0.001. The whole process will be repeated until the convergence condition is satisfied[8].

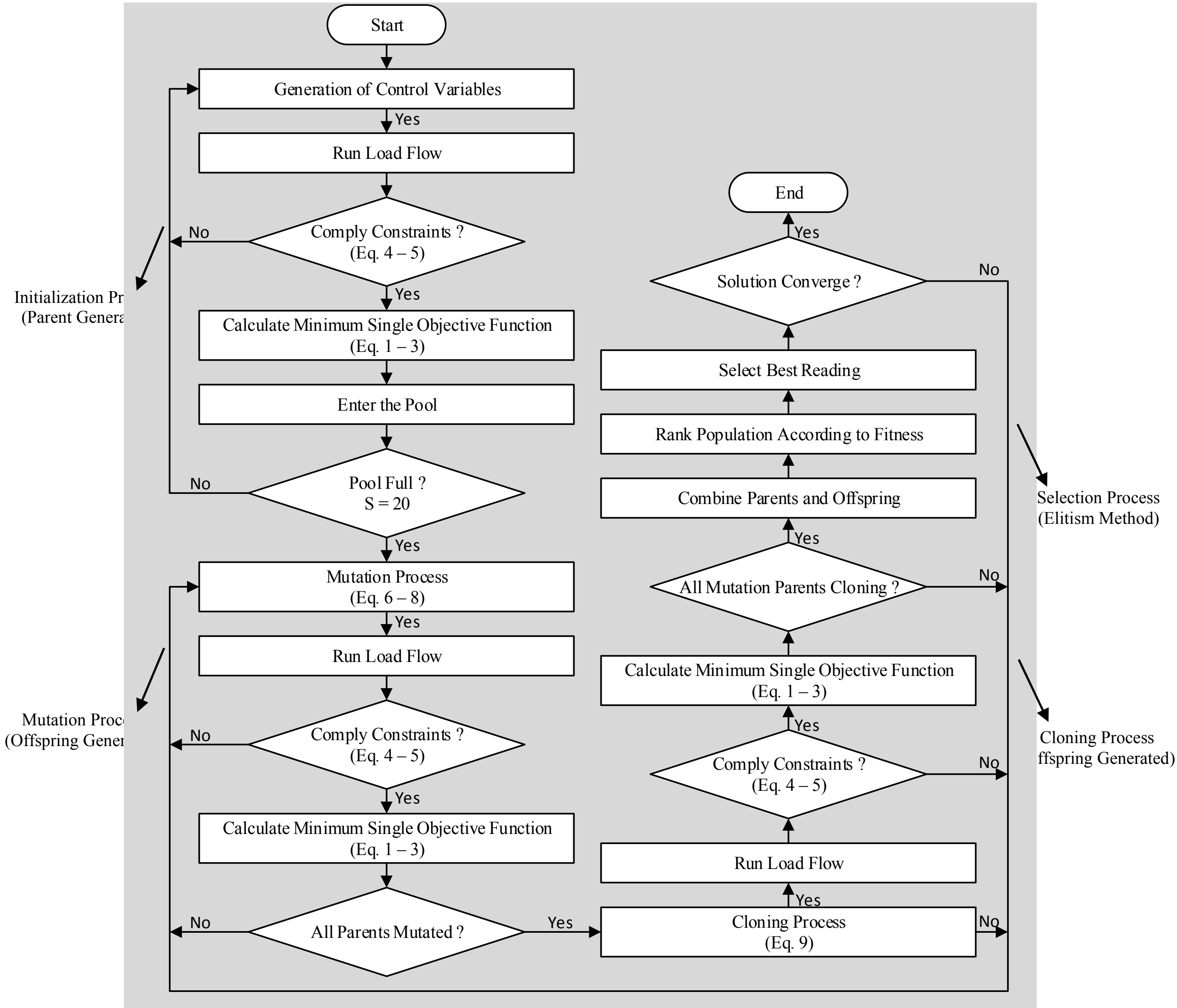


Figure 1: Flow chart of NMEP algorithm based on standard IEEE 26 bus system.

## IV. Result And Discussion

The experiment of New Meta Heuristic Evolutionary Programming algorithm (NMEP) is conducted by using MATLAB software based on standard IEEE 26 bus system. This simulation tested via MATLAB version (R2015a) on a 3.6 GHz processor of Intel i7 personal computer with 16GB of RAM in the laboratory.

The simulation of NMEP is applied for committed generators units namely as Pg2, Pg3, Pg4, Pg5 and Pg26 and tested on the standard IEEE 26 bus system [9]. The setting parameters are used throughout the simulation for up to 12 times in order to get the best solution as displayed in Table 1[10-11]. The three different single objectives function of ED is aimed to minimize the total generation cost, total emission and total system loss as referred to Table 2.

TABLE 1: THE PARAMETER USED TO PRODUCE THE RESULT FOR EACH 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: RESULT OF SINGLE OBJECTIVE FUNCTION RESULT BETWEEN THE NMEP AND AIS ON STANDARD IEEE 26 BUS SYSTEM.

| NMEP | | | AIS | | | Meta-EP | | |
|---|---|---|---|---|---|---|---|---|
| Total System Loss (MW) | Total Generation Cost ($/h) | Total Emission (ton/h) | Total System Loss (MW) | Total Generation Cost ($/h) | Total Emission (ton/h) | Total System Loss (MW) | Total Generation Cost ($/h) | Total Emission (ton/h) |
| 12.4654 | 11990.56 | 15661.35 | 12.5874 | 15521.23 | 15854.85 | 12.4672 | 15577.44 | 20838.47 |
| 12.4305 | 11920.11 | 15656.08 | 12.5197 | 15516.27 | 15786.36 | 12.4563 | 15570.61 | 20817.75 |
| 12.3920 | 11605.62 | 15644.00 | 12.4935 | 15511.68 | 15780.17 | 12.4117 | 15569.05 | 20567.05 |
| 12.3080 | 11510.45 | 15495.16 | 12.4851 | 15503.59 | 15708.01 | 12.4013 | 15563.91 | 19088.76 |
| 12.2979 | 11448.37 | 15407.52 | 12.4552 | 15503.38 | 15595.36 | 12.3735 | 1555871 | 18553.57 |
| 12.2957 | 11264.21 | 15380.77 | 12.4290 | 15497.42 | 15594.36 | 12.3703 | 15544.88 | 18283.26 |
| 12.2351 | 11243.16 | 15356.12 | 12.3192 | 15494.17 | 15352.96 | 12.3387 | 15544.49 | 17676.59 |
| 12.2292 | 10936.30 | 15323.78 | 12.2877 | 15489.12 | 15298.90 | 12.3291 | 15526.89 | 16722.41 |
| 12.2107 | 10853.78 | 15273.14 | 12.2493 | 15487.12 | 15256.48 | 12.2788 | 15500.61 | 16596.20 |
| 12.1359 | 10673.26 | 15119.11 | 12.1587 | 15480.87 | 15056.41 | 12.1560 | 15494.16 | 16438.10 |
| 12.1012 | 10536.47 | 14596.28 | 121244 | 15475.56 | 15010.74 | 12.1545 | 15485.38 | 16343.27 |
| **12.0845** | **10237.76** | **14478.02** | **12.1069** | **15468.14** | **14507.02** | **12.0922** | **15480.40** | **15090.25** |
| **Average time : 43.25426 seconds** | | | **Average time : 44.95013 seconds** | | | **Average time : 43.35988seconds** | | |

TABLE 3: RESULT OF A SINGLE OBJECTIVE FUNCTION BETWEEN NMEP AND AIS FROM MATLAB SIMULATION BASED ON STANDARD IEEE 26 BUS SYSTEM.

| Algorithm | Total System Loss (MW) | Total Generation Cost ($/h) | Total Emission (ton/h) | Average Time (Seconds) |
|---|---|---|---|---|
| **NMEP** | **12.084529** | **10237.76** | **14478.02** | **43.25426** |
| **AIS** | 12.106859 | 15468.14 | 14507.02 | 44.95013 |
| **Meta-EP** | 12.092200 | 15480.40 | 15090.25 | 43.35988 |

Each particular solution in Table 1 presents the achieving of result with respect to single objective functions which were executed 12 times using the identical optimization models as a performance measurement. The obtained results are simplified to the best answers among objective functions over 12 time's execution as in Table 3.

The above table shows that the advantage of employing NMEP allows for 29 ton/h less pollutants to environment, 196.224MW/year less of total system losses and also saving of 5230.38 dollar/h in total generation cost as compared to the AIS algorithm. In contrast, the Meta-EP resulted in 612.23ton/h more emission, increase of 6.7452MW of total system losses a year and caused an additional 5242.64dollar/h of total generation cost as compared to NMEP technique. In addition, the losses during power system operation also influenced the cost of operation since it is equivalent to 51,018.24 dollar/year and 1753.752 dollar/year caused by the losses through AIS and Meta-EP respectively (if charge 0.26 cent =1 kW/h.). Besides, the NMEP approach is much faster in completing the task among AIS and Meta-EP technique.

## V. Conclusion

The proliferation of energy demand and shortage of energy resources makes it compulsory for the availability of a secured load dispatch, as well as the added pressure from public awareness which contributes to the requirement for reduction in toxic waste emissions produced by the power plants. For that reason, this research studied and developed an optimization technique, namely the NMEP that is intended to deliver the demand in an economical way without compromising on the well-being of the environment. Thus, several significant objective functions were established and implemented in the NMEP optimization technique in order to overcome the problems. Based on previous researches, the important objective functions were identified to be the total operation costs, the pollutant emitted as a result of burning of fuel and the total system losses. This objective function was formed individually to be applied using the NMEP, AIS and Meta-EP on tested standard IEEE 26 bus system respectively. From the result, the introduced NMEP gives overall better performance as compared with AIS and Meta-EP approach in terms of minimum total operation cost, less total emission and fewer total system losses during operation. Moreover, the NMEP displays more capability throughout the simulation process for up to 12 times earlier, in comparison to the progressions of AIS and Meta-EP.

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