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NEW DEVELOPMENT OF ANALYSIS TOOL FOR OPTIMIZING GENERATION COST WITH GAS EMISSION VIA AN ELECTROMAGNETISM LIKE ALGORITHM

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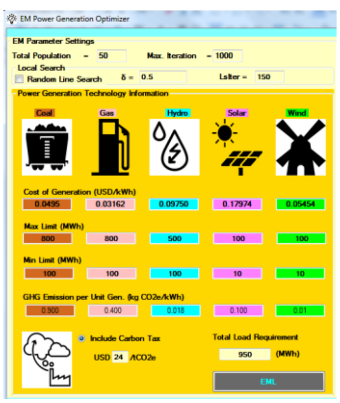
Graphical abstract



Abstract

This paper addresses the preliminary new development results of the evolutionary algorithm technique to optimize the formulated problems incorporating the generation cost with emission gas as objective function or constraints. The power generation cost with emission gas are a complex problem which also the major concerns in electric power generation systems in the Environmental or Economic Dispatch Problems (EDP). Thus, due to environmental concern the electrical utilities required to minimize the emission level while optimizing the thermal generating units at a minimum generating cost and hence, satisfying the load demand and the emissions. In this work the electromagnetism-Like algorithm (EML) has been employed for optimizing generation cost and emission constraints economic dispatch problem. The proposed decision analysis tool software in this work will optimize the generation cost with emission gas objective function. The best generation cost with emission gas solution are obtained from different fuel technology via the developed software.

Keywords: Generation cost; emission gas; electromagnetism-like algorithm; optimization

1.0 INTRODUCTION

Nowadays, the generation cost and greenhouse emission gas become major concerns for the electrical power supply. The economy dispatch problem (EDP) occurs almost in the whole power generating stations that is generating power by various generators units on an optimum economy basis with a promise to meet the need in order to optimize the generation cost and emission. The problem of the EDP is a multi-objective and non-linear.

However, the existing sources of energy production are not ecologically clean. Traditionally, electric power systems operate in such a way that the total fuel cost is minimized regardless of emissions produced. The harmful ecological effects caused by the emission can be reduced by adequate distribution of load between the units of power plant. This problem can be fulfilled by optimization technique and its objective is to reduce the total generation cost of the units and also emissions gas, which regarding to the greenhouse gases like nox , sox , co2 that causes pollution in the environment due to the operation of fossil-fueled thermal generation.

The emission of these pollutants causes global warming that affects not only humans but also other forms of living beings. Thus, it is required to produce electricity at minimum possible cost as well as at a minimum level of pollution. The emission constrained economic load dispatch (ECELD) problem is defined so as to minimize the objective of the operating expenses with emission as constrained [1].

The emission constraint matter has made the economic load dispatch problem a more complex one. This combinatorial nature of ELD makes the problem of conflicting and develop a rigorous mathematical optimization method.

A dynamic programming was used to solve the economic dispatch including transmission losses. The dynamic programming provides an effective solution to handle the operating limits of generators. But the DP approach fails to converge in the case of high dimensional problems [2]. The direct search method had been used in solving ELD problem [3]. Thus, these classical methods do not provide a solution to large scale optimization problem.

The second category of methods for solving optimization type of problems includes stochastic searching algorithms which include simulated annealing, artificial immune system (AIS), genetic algorithm (GA), evolutionary programming (EP) and particle swarm optimization (PSO).

So, optimization techniques are the alternative approach which is flexible and efficient than traditional methods because of their tendency to explore new solutions with appropriate satisfaction of constraints. Genetic algorithm is one of the global optimization technique based on the principles of biological evolution in which accuracy can be improved by increasing the string length. An efficient real coded GA had been used to solve the non convex ELD [8]. However, the GA problem that it requires sufficient space and time to convert into required form which GA deals with binary operators. The improved evolutionary algorithms had been used also for ELD [5]. A memetic algorithm had been used to solve ELD problem [6]. The AIS with value point effect had been used to solve ELD [7]. The functional optimization had been used to solve dynamic ELD with a ramp rate of power output of thermal units [8]. The neural approach had been also used to solve ELD problem on power system [9]. A clonal algorithm had been used to solve ELD [10]. The Quantum-behaved particle swarm optimization (QPSO) algorithm had been used for solving ELD problems [11]. The θ-PSO had been used to solve ELD. The evaluation of the mechanism of PSO is proposed in the novel θ -PSO by changing the speed vector with a phase angle vector [12]. The adaptive Hopfield neural network had been used for ELD [13]. The krill herd algorithm had been used for solving ELD [14]. While, the chaotic and Gaussian PSO approaches had been used to solve ELD problems in power systems [15].

Thus, it is desirable to develop a system that able to optimize the generation cost and emissions. Currently, still not yet have any researchers are focused and using an EML algorithm for optimizing the generation cost and emissions from power generation plants. The developed GUI software for the generation cost and emissions as shown in Figure 1.

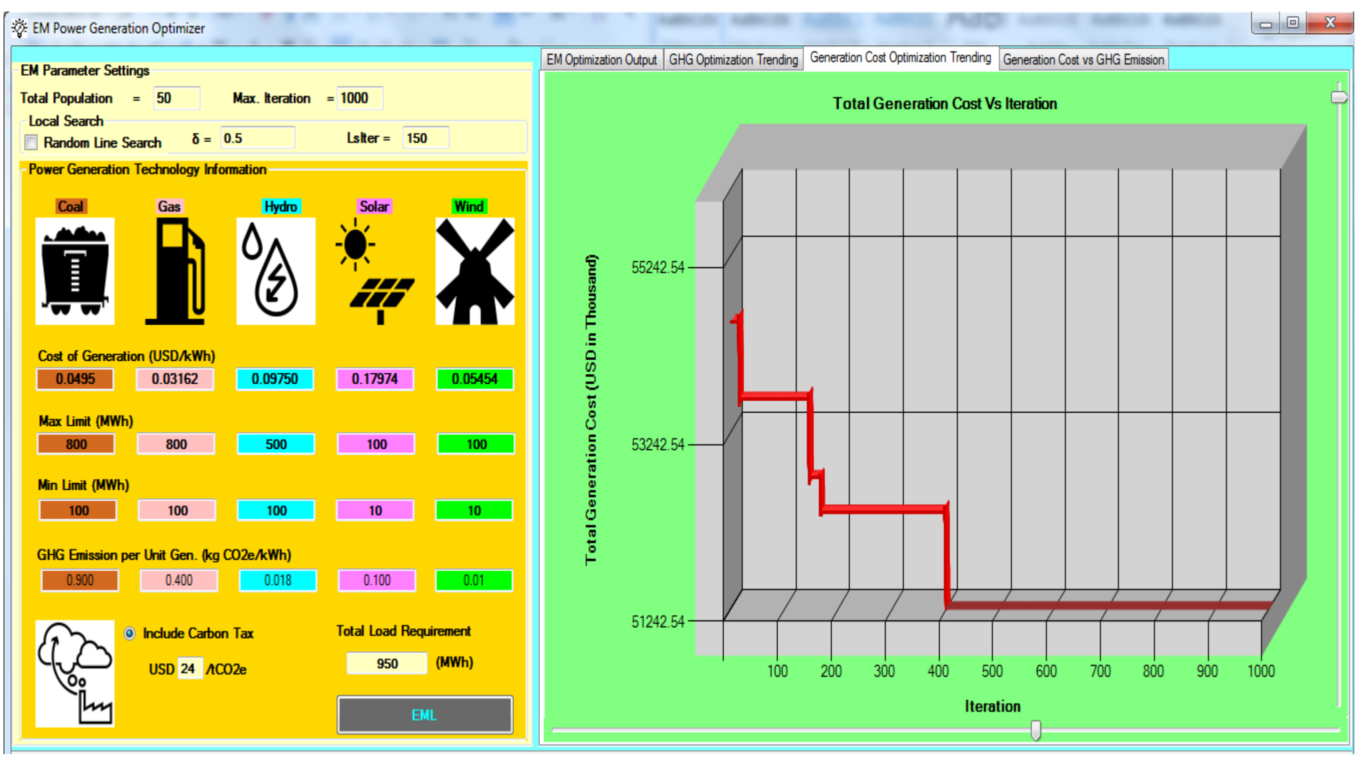


Figure 1 GUI software for decision tool based on EML algorithm

2.0 PROBLEM FORMULATION

The main objective of economic dispatch problem (EDP) is to optimize the best possible combination of power generations cost and best possible emission from this five type technology used, which are the Gas/Fuel, Coal, Hydro, Biomass and Solar. Optimizing the total cost considering both generation cost and emission cost satisfies various constraints under specified operating conditions at the same time. The given objective function and constraint take into consideration in the formulation of EDP problem. The boundary conditions is the maximum capability of the power plant and the lower limit is the minimum requirement for the power plant to be operated. But, due to the feasibility of the power plant example, coal plant could not be stopped from operated.

2.1 Minimize Generation Cost function

The minimize generation cost function can be expressed as in (1).

$$F_1(x) = \min \sum_{i=1}^{k} P_i C_i \tag{1}$$

Where

P_i = Output energy from each power plant (coal, gas, hydro, solar and wind)

C_i = Energy cost

2.2 Minimize Gas Emission function

The minimize gas emission function of pollutants as expressed in (2).

$$F_2(x) = \min \sum_{i=1}^{k} P_i G_i \tag{2}$$

Where

P_i = Output energy from each power plant (coal, gas, hydro, solar and wind)

G_i = Carbon cost

2.3 Constraints

EDP problem is subjected to many constraints depending on the nature of power system under study. In this work the constraint can be expressed as in (3). The load generated must same as the required load.

$$F_3(x) = \sum_{i=1}^{k} P_i = TgE \tag{3}$$

$$F_4(x) = Pi \geq PmL_l \tag{4}$$

$$F_5(x) = Pi \leq PML_l \tag{5}$$

Where

P_i = Output energy from each power plant (coal, gas, hydro, solar and wind)

TgE = Total generated Energy

PmL_l = Plant minimum Load

PML_l = Plant Maximum Load

3.0 METHODOLGY

This work introduces a new implementation of metaheuristic algorithms called electromagnetism-like (EML) algorithm, which proposed by Birbil and Fang [16], for optimization problems with bounded variables in the form of [17]:

$$\text{Min} f(x), \text{ s.t. } L \leq x \leq U \tag{4}$$

where f(x) is the objective function to be minimized, $X = (x_1, x_2, \ldots x_n) \in R^n$ is the variable vector, and L = $(l_1, l_2, \cdots, l_n)$ and U = $(u_1, u_2, \cdots, u_n)$ are the lower bound and upper bound of x, respectively. That is, $l_i \leq x_i \leq u_i$ for i = 1 to n.

The concept of EML algorithm is to simulate the interaction caused by the electromagnetic force between the electrically charged particles. Due to its effectiveness, EML algorithm has been applied to various optimization problems, such as vehicle routing problems [18], feature selection [19], scheduling [20-22] and engineering design problems [23] since the beginning.

3.1 Original EML

In this work the original EML algorithm method had been adopted and implemented. The original EML algorithm of Birbil and Fang [16] uses an electromagnetism like attraction and a repulsion mechanism to move particles as follows. Briefly, the EML algorithm consists of four main procedures: *Initialize*, *Compute F*, *Move* and *Local Search* as shown in the flowchart depicted in Figure 2.

3.2 EML With Local Search And Without Local Search

The purpose of local search is to move a particle to its nearby local optimums. Birbil and Fang [16] indicated that local search can be either omitted or applied to all particles or only the current best particle in the population. Omitting local search, an EML algorithm relies solely on the EML heuristics to search for the optimal solution. However, implementing local search to all particles will cause time consuming and will offer slight improvements over implementation of local search only to the current best particle [16].

Therefore, in this work the EML algorithm had been applied with and without local search to observe the performance of the EML algorithm as shown in the flowchart as depicted in Figure 2 and Figure 3 respectively.

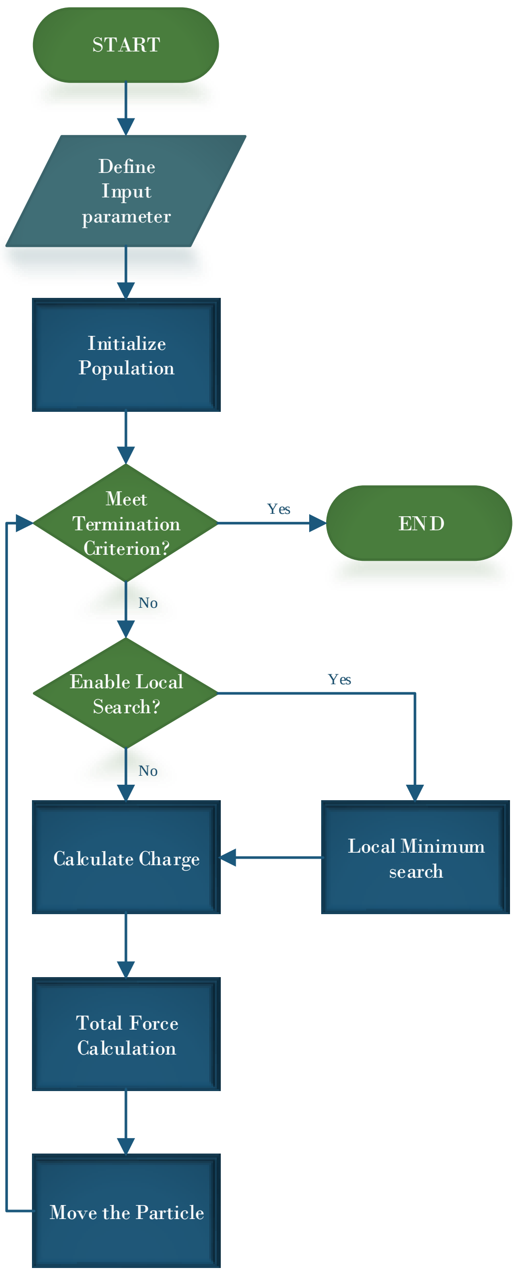


Figure 2 Flowchart for the EML with or without Local Search

Figure 2 shows the general EML algorithm scheme which, considering the local search or not considering the local search in moving a particle to its nearby local optimums. So, without considering local search the EML will only rely on the EML heuristics to search for the optimal solution.

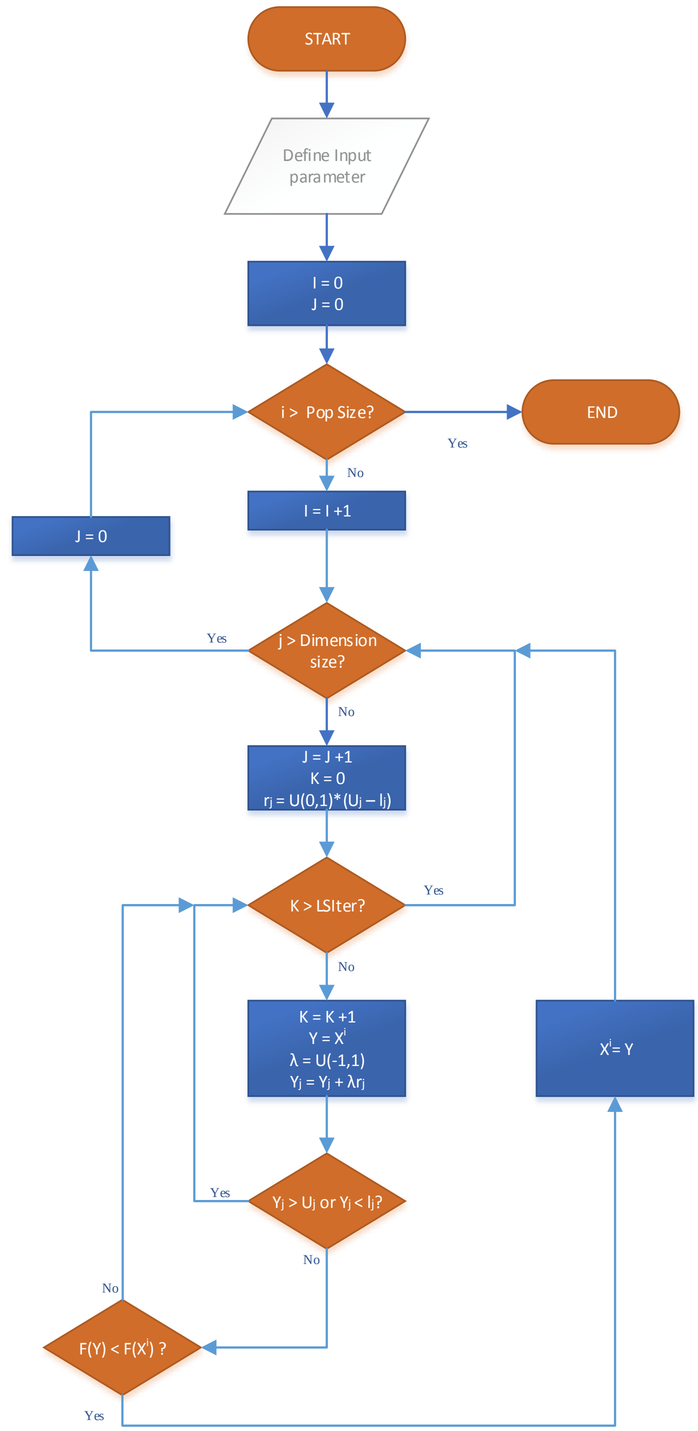


Figure 3 Flowchart for the Local Search

Figure 3 shows the local search implemented in the general EML algorithm scheme in moving a particle to its nearby local optimums.

4.0 RESULTS AND DISCUSSION

4.1 Experimental Setting

For each setting, 30 runs were conducted with the population = 50 and the iteration = 1000, and their average performance was obtained. Each run stops until the maximum number of iterations is reached. In the same run, the same set of initial was generated for the original EML method. In this experiment, the performance study will focus on the local search implementation.

Table 1 Parameters setting for the generation technology

Fuel Technology	Generation Cost (USD/kWh)[25]	CO_{2e} Emission Gas (kg/kWh)[24]
Coal	0.0459	0.900
Gas	0.03162	0.400
Hydro	0.09750	0.018
Solar	0.17974	0.100
Wind	0.05454	0.01

4.2 Local Search test Result

From the literature, by applying local search on the current best particle will improve the performance of their EML method without incurring much overhead [16].

This work will evaluate the performance of the EML methods with and without local search on the best particle. The same local search method which is random line search used by Birbil and Fang [16] in their research had been adopted in this test.

The two parameters setting for random line search are set as in Table 2 [16].

Table 2 Parameters setting for with and without random line search

Parameters	Test 1	Test 2
δ	0.5	0.05
LsIter	150	150

Currently, no attempt is made to adjust these two parameters to fit the objective functions.

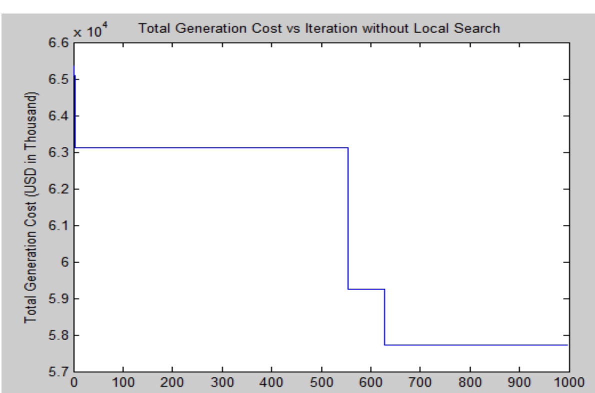


Figure 4 Total generation cost value vs iteration without local search

Figure 4 shows how the total generation cost value vs iteration converges without the implementation local search in the EML by excluding the δ parameter. So, the result obtained in Figure 4 shows that it converged slower than the local search method as depicted in Figure 5 and Figure 6.

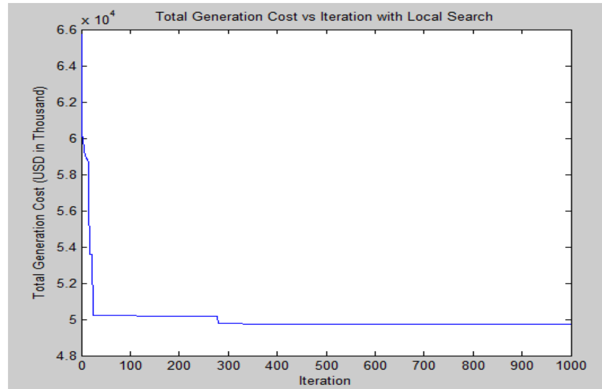


Figure 5 Total generation cost value vs iteration with local search (Test 1)

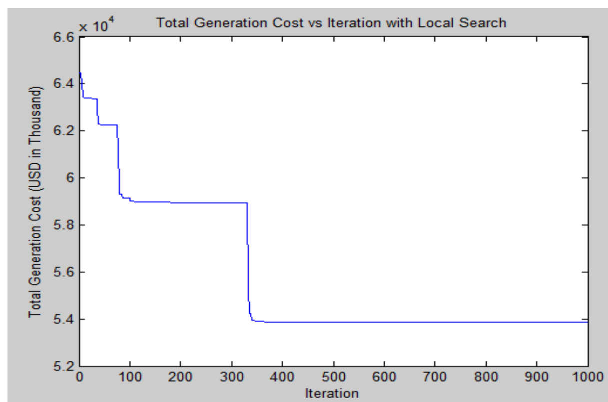


Figure 6 Total generation cost value vs iteration with local search (Test 2)

Figure 5 shows how the total generation cost value vs iteration converges for Test 1 with local search. Figure 6 shows how the total generation cost value vs iteration converges for Test 2 with local search. The comparison result in Figure 5 shows that it converged faster than the local search method as depicted in Figure 6.

4.0 CONCLUSION

An electromagnetism like algorithm optimization algorithm is implemented to solve the generation cost with emission constrained economic load dispatch. The proposed technique provides a well defined balance between exploration and exploitation property during the search. The artificial intelligence-based software tool that applied the electromagnetism like algorithm which is able to correlate energy with the emission level and to optimize for the power generation cost.

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