Lightning Search Algorithm (LSA) Technique For Solving Economic Dispatch (ED) Problem

S.H. Shamsudin, M.N. Abdullah, W.M. Dahalan, N.F. Aswan

Abstract: Economic Dispatch problem involves the scheduling of generating unit outputs that can satisfy load demand at minimum operating cost. This paper proposes a Lightning Search Algorithm (LSA) to optimize the economic dispatch in power system. LSA has three main steps which are transition projectile, space projectile and lead projectile. The proposed method has been applied to solve 3 unit and 6-unit generation system of economic dispatch problem. The objective of this problem is to minimize a total generation cost and to consider the losses. The propose method has been compared with other techniques such as GA, PSO, ABC, and GWO. The comparative result shows that the LSA can provide better solution with a convergence and robustness for solving economic dispatch.

***Index Terms**: Economic dispatch (ED); Fuel cost; Lightning Search Algorithm (LSA); Optimization.*

I. INTRODUCTION

Economic dispatch is one of the main power system problems solved during operational planning stage. It is solved by power system engineers to find the best value of dispatchable generating units output for reducing the total production cost and at the same time abiding the system constraints. Economic dispatch also is an important to optimization problems in power system planning in term of power production plant and fuel cost. Many researchers have tried to find out the best solution to optimally hit the required load to the user. In problem of ED with minimum costs of power generations are shaped to catch the required demand in each by time break. The problem of ED involves several constraints such as prohibited operating zones, ramp rate limits and generation operating limits to determine the lowest cost of operation[1]. The purpose of ED is to minimize the total cost of operation and to achieve a balance in power production by significantly reducing the transmission losses.

The previous researcher using conventional methods, metaheuristic method and hybrid methods.

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The conventional method suggested for solving the economic dispatch problem are such as Linear programming (LP)[2], (NLP) Non-Linear Programming [3] ,(QP) Quadratic Programming [4], and Lagrange Relaxation (LR) [5] have been proposed to solve the Economic Dispatch problems. The Meta-heuristic method can break up the global optimal solution of the non-convex ED problems. The convex and non-convex ED problem has been solving by using Modified Social Spider Algorithm (MSSA).The conventional method that previously used are Genetic algorithm(GA),Particle swarm optimization (PSO) [6], Differential evolution (DE) [7], Seeker Optimization Algorithm (SOA) , Differential harmony search algorithm (DHSA) , Artificial Bee Colony Optimization (ABC) [8], Group Search optimizer (GSO) [9], Immune Algorithm (IA)[10], Backtracking Search Algorithm (BSA)[11] , and Hybrid Harmony search (HSS) with arithmetic crossover operation. From the previous researcher the performance of algorithm still on tests to capture the best outcome in terms of convergence, robustness and optimal solution. In this paper lightning search algorithm (LSA) is used to solve economic dispatch of electrical power. Lightning search algorithm (LSA) was introduced Shareef et.al [12] in 2015. In 2019, Sarker et.al [13] demonstrate the strength of LSA to finding the global minimum value of the objective function for mean absolute error (MAE) . LSA was able to be achieved better result in term of the rising time, settling time, stability, boost maximum voltage, converter efficiency, and response time are excellent condition. From this finding, LSA was implemented on power system to minimize the fuel cost, losses and also to solve the ED problem.

II. PROBLEM FORMULATION

The center of loads and their fuel cost are different because the power plans are not at the same distance. The generation capacity is more than the total load demand and losses when the operating condition is normal. The real power scheduling of each power plant is to find the minimize operating cost. That means the generator real power and reactive power can vary within certain limits to gather a load demand with minimal cost. The ED problem considered a single-objective optimization problem. Its main parts are as follows.

Objective function

The simple economic dispatch problem is the case when transmission line losses are considered. A cost function is presumed to be known for each plant. The problem is to find the real power generation for each plant such that the objective function as by the equation [14].

$$F = \min\left(C_{gT}\right) \quad (1)$$

$$C_{gT} = \sum_{k=1}^{N_g} C_g^{(k)} \quad (2)$$

Where F is the objective function of minimization of the total generation cost of a power system C_{gT}. $C_g^{(k)}$ is define as the generating cost for k^{th} generation unit, and N_g is the number of generators operating in a power system. The generation cost of a generation unit depends on the power output of a generating unit and it can be shown as a quadratic function of the power generated in a generation unit. It can be mathematically expressed as:

$$C_g^{(k)} = \alpha_k + \beta_k P_{G,k} + \gamma_j P_{G,k}^2 \quad (3)$$

where $P_{G,k}$ is the active power generated by k^{th} generation unit and α_k, β_k and γ_k are the cost coefficients of k^{th} generation unit in a power system.

In order to simulate the optimization problem, constraint is compulsory to include into the optimization process. The constraints subjected to the optimization process is power balance constraint. Power balance constraint states that the total power generated by the generation units in a power system should cater to real power losses and all the loads in the power system. The constraint can be expressed as:

$$\sum_{j=1}^{N_g} P_{G,k} = \sum_{n=1}^{N_{bus}} P_{D,n} + P_{loss} \quad (4)$$

where $P_{D,n}$ is the active power demand at n^{th} bus of the power system, P_{loss} and N_{bus} is the total active power loss and the total number of bus in the power system respectively.

Next, the power output of generation unit is bounded between minimum and maximum limitation since operation below the minimum limit can cause the generation unit to become unstable, and operation beyond maximum limit can cause overload on the units. This restriction can be placed as an output power boundary constraint and it can be expressed equally:

$$P_{G,k}^{\min} \le P_{G,k} \le P_{G,k}^{\max} \quad (5)$$

where $P_{G,k^{\min}}$ and $P_{G,k^{\max}}$ are the minimum power output and maximum power output of k^{th} generation unit respectively

III. LSA (LIGHTNING SEARCH ALGORITHM) FOR ECONOMIC DISPATCH PROBLEM

The Lightning search algorithm (LSA) method was introduce a novel metaheuristic optimization to solve the constraint optimization problems [15]. The concept of fast particles which known as projectiles used the mechanism of step leader propagation where the natural phenomenon of lightning is based on LSA. The analytical model is the LSA process made in three steps. The three steps are known as transition projectile, space projectile and lead projectile. Fig 1 represents the process of LSA with ED. The following are the main steps of LSA are as follows:

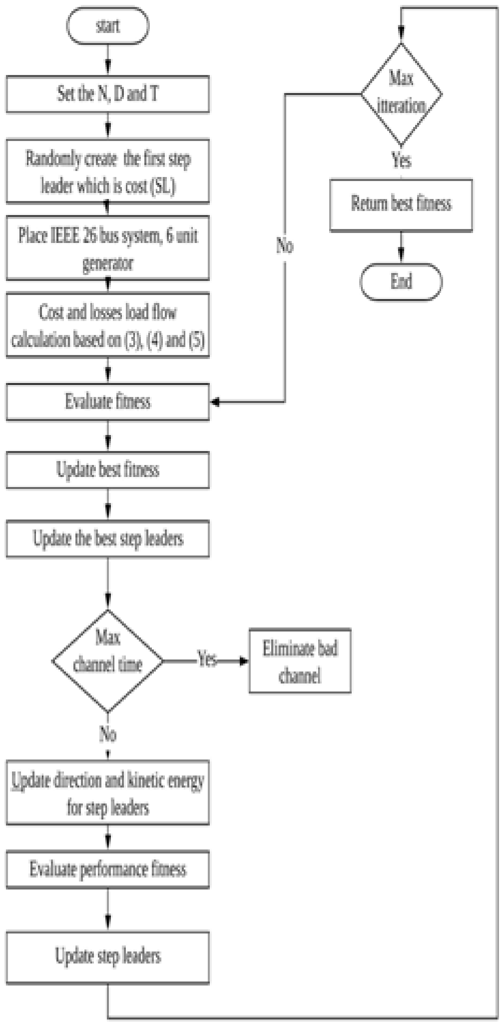

Fig. 1 Flowchart of process for LSA with ED

Initialization

The population of output power, maximum channel time, upper and lower bound were set.

The first step leader

To produce a step leader and a channel each projectile from the thunder cell is assumed. The first population size is the projectile, and the velocity is given by:

$$v_p = \left[1-\left(1/\sqrt{1-\left(v_0/c\right)^2}-sF_i/mc^2\right)^{-2}\right]^{-1/2} \quad (6)$$

Where v_p and v_o are the current velocity and initial velocity of the projectile : c is the speed of light, F_i is the constant ionization rate, m is the mass of the projectile and s is the length of the path traveled.

The population size can be created to increase the number of projectile forking using additional channel. There are two form of forking in the proposed algorithm. First, the projectile created the nuclei collision by symmetrical channel and using the opposite number as in Eq. (7).

$$p_i = a + b - p_i \quad (7)$$

Where, p_i are the opposite and the boundary limits, a and b are the original projectile in one dimension.

After several circulation trials, the energy redistribution of the most failed leader triggered a channel to appear at a successful step leader tip. This happened in the second type of forking. The channel time is defined as the maximum permitted number of trials and used to reallocated unproductive leader, so the population size of step leaders does not rise.

Transition projectile

Transition projectile can be a random number using the standard uniform probability. The probability density function of the standard uniform distribution can be represented as:

$$f(x^T) = \begin{cases} 1/b-a & for\ a \le x^T \le b \\ 0 & for\ x \le a\ or\ x^T \ge b \end{cases} \quad (8)$$

Where x^T is random number that may deliver a solution or the first energy E_{sl_i} of the step leader sl_i, a and b are the lower and upper bounds of the resolution space. For a population of N step leader $SL = [sl_1, sl_2, sl_3, ...sl_N]$ N random projectiles $p^T = [p_1^T, p_2^T, p_3^T, ...p_N^T]$.

Space projectile

By ionizing the section in the area of the former leader tip energy in the next step +1, the leaders are moved using active projectiles. This can be done after changing the N step leader tips. The position of the space projectile $p_S = [p_1^s, p_2^s, p_3^s, ...p_N^s]$ at step+1 can be presented as a random number produced from the exponential distribution by determining the parameter µ. The probability density function of an exponential distribution is yielded from:

$$f(x^s) = \begin{cases} \frac{1}{\upsilon} e^{-x^s/\upsilon} & for\ x^s \ge 0 \\ 0 & for\ x^s \le 0 \end{cases} \quad (9)$$

Eq. (9) shows the direction in the next step can be measured by determined parameter μ. The distance between the lead projectile and the space projectile is accepted under consideration μ_i in the LSA. The position of p_i^s at step+1 is represented by:

$$p_{i\_new}^s = p_i^s \pm \exp\ rand(\upsilon_i) \quad (10)$$

The random number should be subtracted from the Eq. (10) if p_i^s is negative. This happened because the equation provides positive value only. The stepped leader propagation does not guarantee by the original position $p_{i\_new}^s$ if the projectile energy $E_{p\_i}^s$ is greater than the step leader E_{sl_i} for a good resolution. If $p_{i\_new}^s$ provides a good resolution at step+1, then the corresponding stepped leader sl_i is prolonged to a new position sl_{i_new} and p_i^s is updated to $p_{i\_new}^s$. Then, if stays unaffected until the next step. If $p_{i\_new}^s$ covers sl_{i_new} past the extended leader during this process it can turn into the lead projectile.

Lead projectile

The projectile connected with the ionize large section in front of the leader that has moved nearest to the ground from the step leader. The standard normal distribution with the form parameter μ and the scale parameter σ from the random number can be presented as a lead projectile. The normal probability density function $f(x^L)$ is represented as:

$$f(x^L) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x^L-\upsilon)^2/2\sigma^2} \quad (11)$$

The current position clear by the form parameter shows the randomly produce lead projectile as Eq (11).

The scale parameter by a manipulation ability also in this projectile. The best solution for the scale parameter σ exponentially reductions as improvement towards the earth as μ_L for the lead projectile p^L is taken as p^L in the LSA. The position of p^L at step+1 can be represented as:

$$p_{new}^L = p^L + normrand(\upsilon_L, \sigma_L) \quad (12)$$

The normal distribution function produces a *normrand* by a random number. The projectile lead energy $E_{p\_i}^L$ is greater than step leader E_{sl_i} to extend the resolution for the new lead projectile position p_{new}^L does not promise the step leader increase . The consistent step leader sl_i is extended to a new position sl_{i_new}, and p^L is updated if p_{new}^L provides a good solution at step+1. The space projectile remains unmoved until the next step.

IV. SIMULATION RESULT

The proposed LSA for solving economic dispatch problem has been tested on 2 benchmark IEEE standard test systems [16] and the results are compared with other methods available in the literature to demonstrate its effectiveness. The simulations were performed in MATLAB 2019a software on Intel Core i5-6500@3.20GHz, 8GB RAM system.

Test system 1: 3-unit system

The 3 unit test system was tested at load demand of 850 MW generator limit constraint [17]. The cost coefficient of all thermal generating unit are taken from [18].

The parameter of LSA algorithm considered are population size is 20 and the iteration is 100. The corresponding result are compared with Genetic Algorithm [19], Particle Swarm Optimization [19], Artificial Bee Colony [19] and Grey Wolf Optimizer [17]. Table 1 show the comparison of results with diverse algorithms and it is found that the optimal value of fuel cost 8227.71 $/h at transmission losses of 3.840 attained by LSA. The cost is much less comparatively with GA, PSO, ABC and GWO.

The convergence curve of 3-unit system is presented in Fig1

Table. 1 Generating Unit System (load demand = 850 MW)

Unit power (MW)	*GA*	*PSO*	*ABC*	*GWO*	*LSA*
P1	342.255	394.524	300.266	300.51	**372.23**
P2	127.418	200	149.733	149.81	**153.30**
P3	340.320	255.475	400	399.67	**328.30**
Losses	4.280	4.060	3.940	3.940	**3.840**
Fuel cost ($/h)	8575.64	8280.81	8253.1	8253.10	**8227.71**

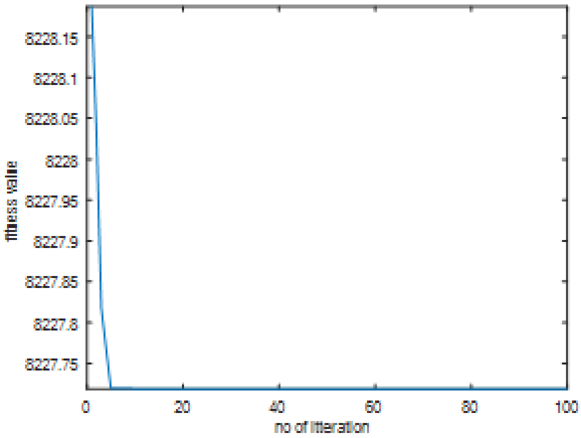

Fig. 2 Convergence curve for 3 unit generating system (850 MW)

Test system 2: 6-unit system

The 6-unit test system [20] was tested at a load demand of 1263 MW generator limit constraints. 20 runs were performed at a maximum population size of 30 and the iterations were limited to 500. The best result in 20 runs is shown in Table 2 along with results of TS [20], CBA [21], PSO [22] and MABC [23] . It can be seen from Table 2 that LSA algorithm achieved minimum fuel cost 15448.7 $/h at transmission losses of 12.761 and the cpu time is 450.59 second. Convergence curve is demonstrated in Fig. 3 respectively. Robustness for 6-unit generator with 20 runs also presented in Fig. 4

Table. 2 Unit Generating System (load demand =1236 MW)

Unit power (MW)	*TS*	*CBA*	*PSO*	*MABC*	*LSA*
P1	459.0753	447.4187	447.49	447.503	**445.218**
P2	185.0625	172.8255	173.32	173.317	**178.876**
P3	264.2094	264.2759	263.47	263.467	**259.494**
P4	138.1222	139.2469	139.05	139.365	**142.471**
P5	154.4716	165.6526	165.74	165.472	**166.714**
P6	74.9	86.12	87.12	87.32	**82.79**
losses	12.9422	12.9848	12.95	12.958	**12.761**
Fuel cost ($/h)	15454.89	15451.23	15450	15449	**15448.7**

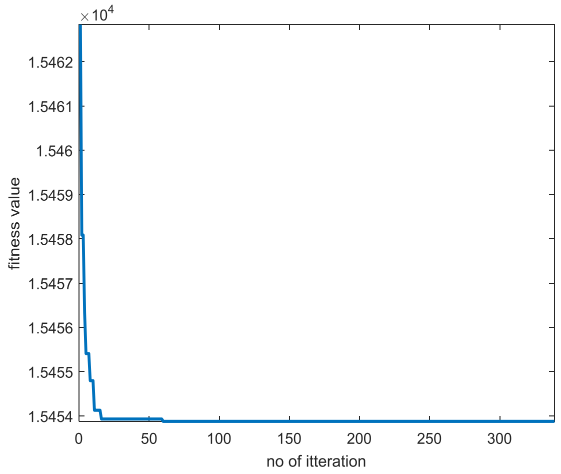

Fig. 3 Convergence curve for 6 unit generating system

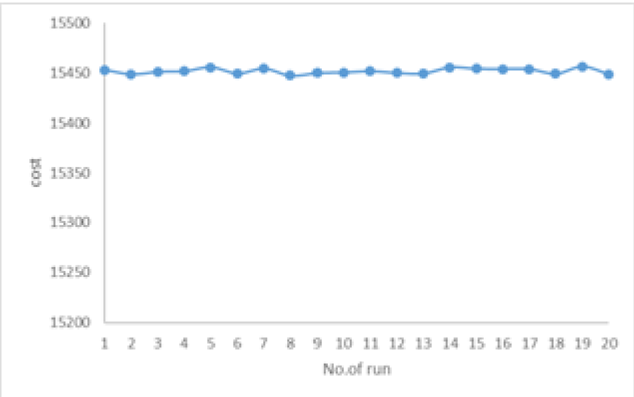

Fig. 4 Robustness of LSA for 6 Generating Unit

V. CONCLUSION

In this study paper, the application of LSA for solving the economic dispatch has been presented. The performance of LSA is tested for small power plants. The efficiency of proposed LSA is tested with the standard IEEE bus system consisting of 3 units generating system and 6 unit generating system. The result obtained show the LSA has been successfully implemented to solve ED problem. It found that, LSA can provide the result in term of minimizing total fuel cost and losses as compared to GA, PSO, ABC and GWO for small scale power system. LSA can also be tried out for multi objective optimization problems and economic dispatch problems that incorporate hybrid sources. All the presently tested systems were successfully solved by LSA and further improvement may be achieved by improving LSA algorithm or mixing it with different hybrid algorithm.

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