# Combined Computational Intelligence Approach for the Power System Optimization Problem

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***Abstract*—A power system optimization is one of the major problems in the operating performances of the existing system. This problem takes place on the various technical cases to get optimal conditions of the system. Moreover, many approaches have been implemented to carry out the solution under operational constraints. This paper presents Thunderstorm Algorithm (TA) and Artificial Salmon Tracking Algorithm (ASTA) for defining the optimal strategy of the power system optimization based on the unit commitment. Both algorithms are tested on the IEEE-62 bus system, whereas, results show that ASTA and TA can be combined together to solve the power system problem. These algorithms have been applied to predict the power consumption and it has good performances while searching for the optimal solution. These results also show that the economic dispatch problem is conducted to the power production while the algorithm is performed in good characteristics.**

***Keywords*—algorithm; dispatch; emission; optimization; power**

## I. INTRODUCTION

One of the optimization problems on the power system operation is a unit commitment (UC) which is consisted of the various generating unit combination. The UC is used to fulfill the energy customer service which is correlated with the total power demand. Technically, the power demand is one of the most considerations on the power production. This factor is associated with energy usages on the consumer site patterns related to the UC over the day, night, week, seasons and holidays. Deal with this condition, a demand forecasting strategy is a very important policy to meet the power production in the behavior of the energy players. In addition, the optimal power production is also urgent to cover all possible combination between existing power plants as a unit commitment. The UC is commonly approached using an economic dispatch (ED) problem [1]–[7] while the optimal allocation of power outputs belongs to the various generators available to serve the load [8]–[11] considering also an emission dispatch (EmD) problem for decreasing pollutants [6], [12]–[14].

Presently, the ED and EmD are an important optimization problem in the power system operation which can be solved using various techniques. An intelligent computation (IC) is more popular than classical approaches to carrying out this problem [7], [9], [15]–[20]. Since an early idea of the IC, many methods have been proposed based on own inspirations [13], [21] and many natural phenomena or biological processes have been also adopted as the inspiration [12], [21], [22]. Currently, many algorithms have also been proposed which are conducted to phenomena or entities in nature [22]–[26]. These versions have been advanced to increase computational performances through hierarchies and procedures for sequencing orders of the algorithm [8], [14], [27]. In line with previous efforts, this paper presents an emphasizing of thunderstorm mechanism and salmon tracking applied to the power system problem considered various operational limitations.

## II. ALGORITHMS OVERVIEW

Many computational bits of intelligence are developed based on the natural phenomenon and behavior [21], [28]–[31]. In these works, one other is adopted from thunderstorm mechanisms which are recognized by cloud shapes and a pre-signal. In nature, these mechanisms are mitigated from the charge ignition for the interaction between the negative charge [30], [32], [33]. In detail, the Thunderstorm Algorithm (TA) is depicted in Fig. 1 with transforming structures in computation processes are Cloud Phase: Streamer Phase; and Avalanche Phase [8], [11], [34]. This figure illustrated a striking propagation from the sky to earth as a charge moving direction.

In particular, artificial salmon tracking algorithm (ASTA) is also presented in these studies which are designed as given Fig. 2. ASTA is adopted from behaviors of Salmon fish in nature while the salmon run is the moving time migrated from the ocean, swim to the upper reaches of rivers where spawning on gravel beds [35]. Many works were explored and developed to understand the migration situation [28], [29], [31], [35]. In these works, ASTA is presented in computational parameters cover salmon number, surviving factor, mouth river, tracking round, migrating period. As given in Fig. 2, these parameters are covered for Exploring behaviors and Surviving behaviors.

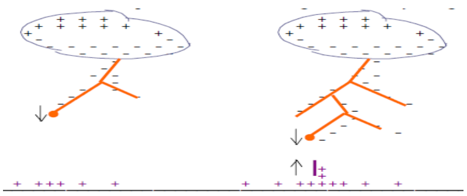

Fig. 1. Illustration of the striking propagation

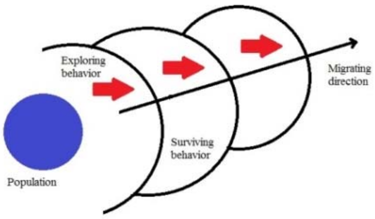

Fig. 2. Principles of the artificial salmon tracking algorithm

## III. Method and Approach

Many technical problems are approached using a model which is used to fit the data, simulation, and forecasting. A model can also be also used to plan the amount of evaluation required to meet desired levels in various fields [1]–[5]. In addition, the model is used to find the optimal allocation of the UC among the various generators available to serve the load [8]–[11], [34], [36]–[38]. Recently, many strategies are developed to explore a UC considering the fuel cost, emission, transmission line losses, weighting factors, and others [5], [23]–[25]. In these works, the UC covers ED and EmD problems as discussed in [6], [12]–[14] and integrated to become an economic and emission dispatch (EED) problem under operational limitations [14], [25], [39]–[41]. Furthermore, many works have used the EED to describe some economical measurements on the desirable targets [4], [14], [38], [42], [43]. In these studies, the EED is formulated using mathematical statements for defining the objective function and technical constraints [6], [10], [26], [39] considering the IEEE-62 bus system as a sample model of the power system. This model consists of 62 buses; 89 lines; and 32 load buses. This system is also supported by 19 generating units. In addition, this system is constrained by 10% of the loss limit; 0.5 of the weighting factor; and 0.85 kg/h of the emission standard; 5% of voltage violations; 95% of the power transfer capability; and banded on upper and lower power limits.

Moreover, TA and ASTA are designed based on its structures and procedures whereas both interactions are illustrated in Fig 3. TA is implemented on a standard model of the power system based on the sequencing orders as depicted in Fig. 1 while ASTA uses Fig. 2 for the processes. In these works, TA is compiled using the cloud phase; streamer phase; and avalanche phase in terms of 1 of the avalanche; 25 of the cloud charge; 100 of the streaming flow; and 4 of the hazardous factor. On the other hand, ASTA is also compiled based pseudo-codes covered for the salmon number, surviving factor, mouth river, tracking round, migrating period. In details, ASTA is presented using 100 of the salmon number, 0.25 of a surviving factor, 100 of the mouth river, 100 of the tracking round, 1 of the Migrating period, and 50 of the population. Based on Fig. 3, the procedures are subjected to the 0bjective function, TA processes, Unit Commitment, ASTA processes, and the updating processes.

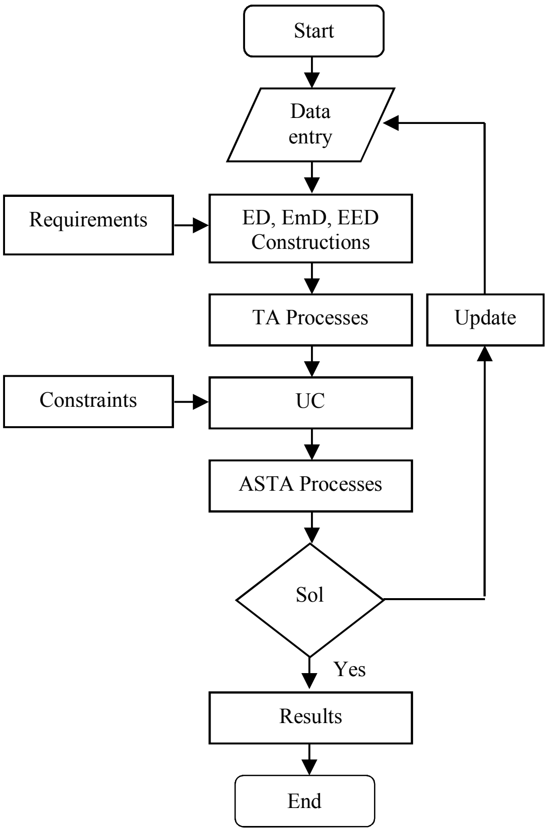

Fig. 3. TA and ASTA interaction

## IV. Results and Discussion

In this section, the system is modeled using IEEE-62 bus system with main parameters of generating units are listed in Table I. This table informs for the coefficients and power limits. Moreover, graphical performances of the computation are given in Fig. 4 and Fig. 5. From these figures, it is known that Fig. 4 illustrates a computational convergence speed which is searched in 17 iterations while these compiling processes need 82.1 s. Moreover, the optimal solution of the EED is 12,005.6 $/h after started at 17,408.2 $/h at the first step. This characteristic also describes that the computation is performed in smooth and stable processes with the consuming time is given in Fig. 5. In total, this simulation is completed in 533.3 s. In these works, the simulation is addressed to evaluate a computing ability while searching the optimal solution of the EED problem as the optimal power production based on the IEEE 62 bus system considering several requirements and constraints. By considering 2,221.2 MW of the power load, the system has produced 2,387.9 MW from existed generating units. It means that this operation has 166.7 MW of the total power loss or around 6.9%.

TABLE I. GENERATING UNIT COEFFICIENTS

| Gen | Fuel Cost | | | Emission | | | Limit | |
|---|---|---|---|---|---|---|---|---|
| | a ($/MWh2) | b ($/MWh) | c | α (kg/MWh2) | β (kg/MWh) | γ | Pmin (MW) | Pmax (MW) |
| G1 | 0.00700 | 6.80 | 95 | 0.0180 | -1.8100 | 24.300 | 50 | 300 |
| G2 | 0.00550 | 4.00 | 30 | 0.0330 | -2.5000 | 27.023 | 50 | 450 |
| G3 | 0.00550 | 4.00 | 45 | 0.0330 | -2.5000 | 27.023 | 50 | 450 |
| G4 | 0.00250 | 0.85 | 10 | 0.0136 | -1.3000 | 22.070 | 0 | 100 |
| G5 | 0.00600 | 4.60 | 20 | 0.0180 | -1.8100 | 24.300 | 50 | 300 |
| G6 | 0.00550 | 4.00 | 90 | 0.0330 | -2.5000 | 27.023 | 50 | 450 |
| G7 | 0.00650 | 4.70 | 42 | 0.0126 | -1.3600 | 23.040 | 50 | 200 |
| G8 | 0.00750 | 5.00 | 46 | 0.0360 | -3.0000 | 29.030 | 50 | 500 |
| G9 | 0.00850 | 6.00 | 55 | 0.0400 | -3.2000 | 27.050 | 0 | 600 |
| G10 | 0.00200 | 0.50 | 58 | 0.0136 | -1.3000 | 22.070 | 0 | 100 |
| G11 | 0.00450 | 1.60 | 65 | 0.0139 | -1.2500 | 23.010 | 50 | 150 |
| G12 | 0.00250 | 0.85 | 78 | 0.0121 | -1.2700 | 21.090 | 0 | 100 |
| G13 | 0.00500 | 1.80 | 75 | 0.0180 | -1.8100 | 24.300 | 50 | 300 |
| G14 | 0.00450 | 1.60 | 85 | 0.0140 | -1.2000 | 23.060 | 0 | 150 |
| G15 | 0.00650 | 4.70 | 80 | 0.0360 | -3.0000 | 29.000 | 0 | 500 |
| G16 | 0.00450 | 1.40 | 90 | 0.0139 | -1.2500 | 23.010 | 50 | 150 |
| G17 | 0.00250 | 0.85 | 10 | 0.0136 | -1.3000 | 22.070 | 0 | 100 |
| G18 | 0.00450 | 1.60 | 25 | 0.0180 | -1.8100 | 24.300 | 50 | 300 |
| G19 | 0.00800 | 5.50 | 90 | 0.0400 | -3.000 | 27.010 | 100 | 600 |

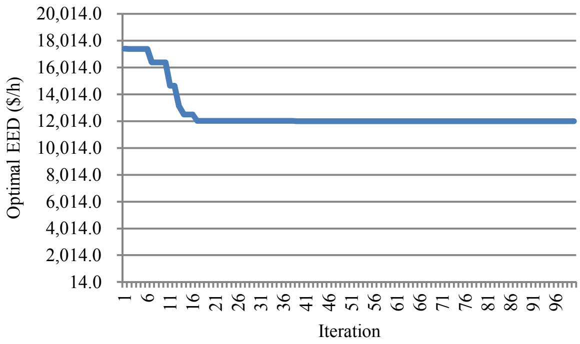

Fig. 4. Computational speed of the optimal solution

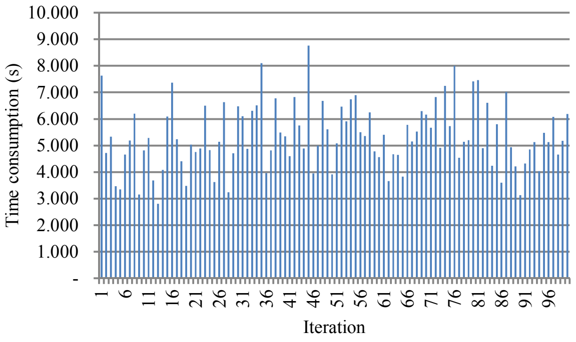

Fig. 5. Computational time consumption

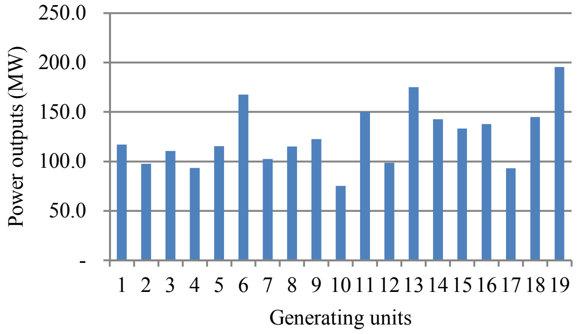

Fig. 6. Individual generating unit commitment

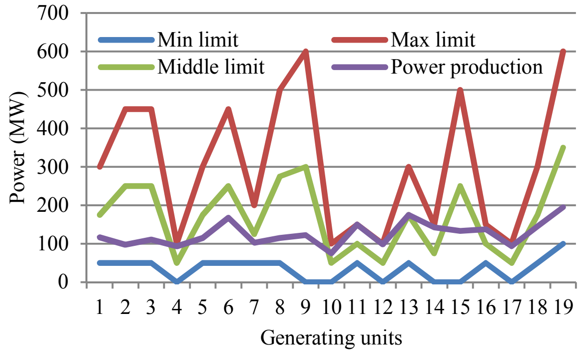

Fig. 7. Power production evaluation

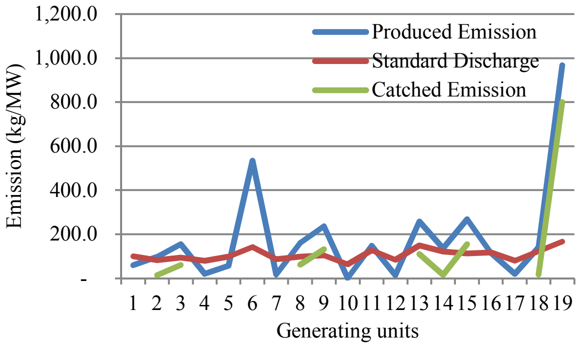

Fig. 8. Emission effects of generating units

TABLE II. OPERATING COST OF GENERATING UNITS

| Gen | Power (MW) | Fuel cost ($) | Emission Compensation ($) | Operating Cost ($) |
|---|---|---|---|---|
| G1 | 117.2 | 988.1 | 0 | 988.1 |
| G2 | 97.5 | 472.3 | 10.6 | 482.9 |
| G3 | 110.6 | 554.9 | 45.2 | 600.1 |
| G4 | 93.4 | 111.2 | 0 | 111.2 |
| G5 | 115.6 | 631.8 | 0 | 631.8 |
| G6 | 167.5 | 914.3 | 293.8 | 1,208.1 |
| G7 | 102.6 | 592.6 | 0 | 592.6 |
| G8 | 115.0 | 720.2 | 46.8 | 767.0 |
| G9 | 122.6 | 918.3 | 98.8 | 1,017.1 |
| G10 | 75.3 | 107.0 | 0 | 107.0 |
| G11 | 150.0 | 406.3 | 15.6 | 421.8 |
| G12 | 98.7 | 186.2 | 0 | 186.2 |
| G13 | 175.0 | 543.1 | 82.5 | 625.7 |
| G14 | 142.5 | 404.4 | 11.4 | 415.8 |
| G15 | 133.2 | 821.2 | 116.1 | 937.3 |
| G16 | 137.9 | 368.6 | 0 | 368.6 |
| G17 | 93.2 | 110.9 | 0 | 110.9 |
| G18 | 144.8 | 351.1 | 12.4 | 363.5 |
| G19 | 195.3 | 1,469.3 | 600.6 | 2,069.9 |
| Total | 2,387.9 | 10,671.8 | 1,333.8 | 12,005.6 |

As the implication of this unit commitment, generating units also produce individually power outputs within various portions of the pollution as detailed in Fig. 6. In addition, the system operation is also required by many conditions and situations. By considering the operating in terms of maximum, minimum, and middle limits, the power production is evaluated as depicted in Fig. 7. This figure informs the condition of each generating unit on the base of the power capability to give a contribution to the UC. In particular, caused by over standard productions, the generating unit gives an environmental effect as illustrates in Fig. 8. These emissions should be filtered at generating units around 1,778.4 kg/h. In total, generating units release in 3,398.6 kg/MW of the emission even it is permitted only 1,029.7 kg/MW under an emission standard. Economically, the system is optimized in 12,005.6 $/h for the operating cost covered the fuel procurement and the emission compensation. In particular, Table II presents the details of the operating fee. The fuel consumption needs 10,671.8 $/h while 1,333.8 $/h is used for the pollutant compensation. This table also informs that generating units take place on different power capacities to cover the total load demand. Moreover, the system has released the pollutant in various results over under environmental standard. Several generating units are still operated with the lower pollution is associated with the emission compensation fee.

## V. CONCLUSION

In general TA and ASTA cam be combined to solve the problem applied to an IEEE-62 bus system. These algorithms have used to search the optimal balance of cost and emission aspects. Results show that the problem is carried out in various power outputs, emission discharges, and optimized operating costs while the optimal point is obtained. Moreover, real applications are devoted.

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