Combined Economic and Environmental load dispatch using multi objective Tunicate Swarm Algorithm

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Abstract - Economic utilization and environmental impact are contradictory objectives in the problem of power generation scheduling where sustainable development of a country is partially depended on these two. The objective of this paper is to schedule the output of committed generating units where both cost and emission of electric power generation have been minimized without shedding any load and satisfying all units and system equality and inequality constraints. In this paper, a new swarm behaviour-based meta-heuristic technique named Tunicate Swarm Algorithm (TSA) has been implemented to solve this problem and the efficacy of this algorithm has also been compared. A six generators system connected with four buses has been considered in this paper as a test model.

Keywords - Tunicate Swarm Algorithm (TSA); Multi-objective economic Environmental scheduling; Meta-heuristic technique

1.0 Introduction

In global energy market, fossil fuel-based power generation is more reliable than other modes. Enormous increase of pollution due to release of CO_2, NO_2 and SO_x into the atmosphere in thermal power generation affects the human lives and the ecosystems. After the passage of the Clean Air Act Amendments in November1990, researchers have focused on not only economic constraints as well as environmental constraints. Several optimization techniques have already been applied in economic dispatch and environmental dispatch problem. Several metaheuristic and stochastic algorithms have been applied in multi objective framework inspired from biological phenomenon to optimize both cost and emission. Different types of swarm intelligence-based algorithms are being applied by the researchers due to its ease. Jiejin et al. proposed a multi-objective chaotic ant swarm optimization technique to optimize both cost and emission (Cai,2010).Theofanis et al. applied firefly algorithm to solve the problem of economic emission load dispatch(Apostolopoulos, 2011). Improved harmony search (IHS) technique has been applied by Suresh et al. to optimize cost and emission of thermal power generation incorporating wind energy (Damodaran,2017). Soumyadip et al. have employed multi-objective particle swarm optimization (MOPSO) for economic environmental load scheduling of six-unit thermal power generation (Roy, 2021).Economic generation schedule of thermal power system incorporating optimized emission of thermal power system using grey wolves' optimization has been proposed by Kalyan et al(kadali, 2017). The objectives of this paper are sorted in below:

- Proposing economic scheduling and environmental scheduling using TSA of six thermal generating units and considering power loss.
- Proposing multi-objective economic and environmental scheduling using TSA of six thermal generating units and considering power loss.

- Compare the results of algorithms and showing superiority of result obtained from TSA.

This paper is organized as follows. Section 1 is introduction. Section 2 presents problem formulation. Section 3 presents methodology of the work where mapping technique is discussed. Section 4 shows performance result of the method and comparison with existing techniques. Last section presents the conclusions of the work.

2.0 Problem Formulation:

A six generators test system has been considered where plant 1, plant 2 and plant 3are interconnected through four buses. The test system is given in below.

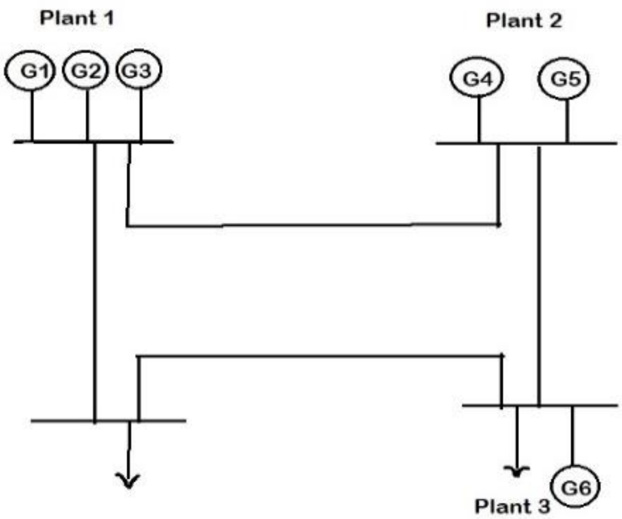

Fig.1 A 4-bus test system with 6 generators

Cost optimization function F_1 and emission optimization function F_2 are quadratic functions of generated power of thermal generating units where the G stands for thermal generation unit.

$$F_1 = \sum_{i=G} (a_i p_i^2 + b_i p_i + c_i) \quad ..(1)$$

$$F_2 = \sum_{i=G} (d_i p_i^2 + e_i p_i + f_i) \quad ..(2)$$

The transmission power loss P_{Loss} is a function of power generated by 6 units and B loss coefficients and it can be stated as below (Roy,2021).

$$P_{Loss} = \sum_{\alpha=1}^{N_{TP}} \sum_{\beta=1}^{N_{TP}} P_\alpha B_{\alpha\beta} P_\beta \quad ..(3)$$

Power generation must be equal to the summation of power demand and power loss.

$$P_{Generation} = P_{Demand} + P_{Loss} \quad ..(4)$$

Where P_α and P_β are the power generated by 6 units and the number of thermal power plants is denoted by N_{TP}. Hence 900 MW is the power demand of this test system.

Table-1: Fuel cost coefficients, greenhouse emission coefficients and maximum and minimum range of power of six generators, B loss coefficient

Thermal Unit Data(Roy,2021)									
Plant	Unit	Fuel Cost coefficients			Greenhouse Gas Emission Coefficients			P_{Min}	$PMax$
		a_i	b_i	ci	d_i	e_i	f_i		
1	G1	0.15274	38.54	756.8	0.00419	0.32767	13.8593	10	125
	G2	0.10578	46.159	451.33	0.00419	0.32767	13.8593	10	150
	G3	0.02803	40.397	1049.3	0.00683	-0.54551	40.2669	40	250
2	G4	0.03546	38.306	1243.5	0.00683	-0.54551	40.2669	35	210
	G5	0.02111	36.328	1658.6	0.00461	-0.51116	42.8955	130	325
3	G6	0.01799	38.27	1356.7	0.00461	-0.51116	42.8955	125	315

B loss coefficient (Roy,2021) is

$$B_{ij}=\begin{matrix} 0.000091 & 0.000031 & 0.000029 \\ 0.000031 & 0.000062 & 0.000028 \\ 0.000029 & 0.000028 & 0.000072 \end{matrix}$$

3.0 Methodology:

The TSA, a bio-inspired meta-heuristic and stochastic optimization algorithms based on jet propulsion and swarm behaviours of tunicates which are marine invertebrate animals and member of the subphylum during the navigation and foraging process. TSA was proposed by Satnam Kaur et al.(Kaur, 2020).Optimal solutions in comparison to other competitive algorithms can be obtained from results of TSA and solution of real case studies having unknown search spaces can be solved with this algorithm.

Implementation of vector $\bar{A}$ is for calculation of new search agent position and avoiding conflicts of search agent position.

$$\vec{A} = \frac{\vec{G}}{\vec{M}}\vec{G} = c_2 + c_3 - \vec{\vec{FF}} = 2c_1 \qquad ..(5)$$

The variables c_1,$c_2$andc_3 should have a value in the range between 0 and 1. $\bar{G}$ stands for gravity force and F stands for water flow advection in deep ocean. The social force is represented by $\bar{M}$ between search agents and $M$is calculated by

$$\vec{M} = P_{min} + c_1.P_{max} - P_{min} \qquad ..(6)$$

The initial and subordinate speeds are denoted by P_{min} and P_{max} .The movement towards the direction of best neighbour $\overrightarrow{PD} = |\vec{FS} - rand.P_p(x)|$ ..(7)

$\vec{PD}$ is the distance between food source and search agent, i.e., tunicate. Position of tunicate is denoted by vector $\overrightarrow{P_P(x)}$ and random no. is denoted by rand. The search agent towards best position is given by

$$\overrightarrow{P_P(x)} = \begin{cases} \vec{F}S + \vec{A}.\overrightarrow{PD}, if\ rand \geq 0.5 \\ \vec{F}S + \vec{A}.\overrightarrow{PD}, if\ rand < 0.5 \end{cases} \quad .. (8)$$

Where $\overrightarrow{P_P(x')}$ is the updated position of tunicate with respect to the position of food source $\vec{F}S$.

4.0 Result & Discussion:

Three different cases have been discussed here to obtain scheduling of thermal units to optimize cost and emission.

4.1 Case I (Economic scheduling): Scheduling where only cost is optimized and corresponding emission is obtained. Here a comparison table between TSA and hierarchical particle swarm optimization (HPSO) is given in table-2.

Table-2 Comparison of result with TSA and HPSO for the objective of cost minimization

HPSO (Roy,2021)		TSA	
Optimized Cost	Corresponding Emission	Optimized Cost	Corresponding Emission
46642.04	793.9329	45463.7393	871.0031

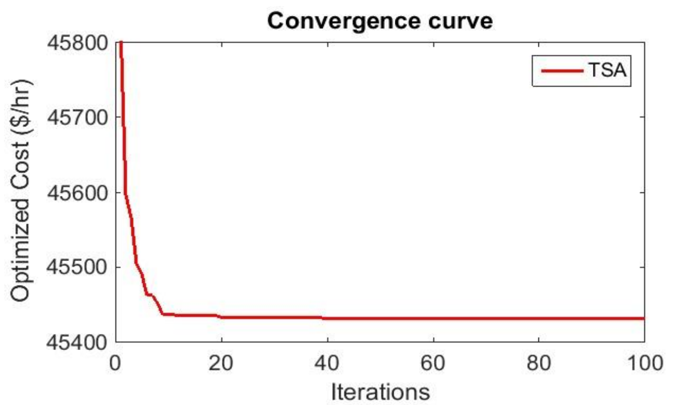

Fig. 2 Convergence curve of TSA for the objective of cost minimization

4.2 Case II (Environmental scheduling): Scheduling where only emission is optimized and corresponding cost is obtained. Here a comparison table between TSA and hierarchical particle swarm optimization (HPSO) is given in table-3.

Table-3 Comparison of result with TSA and HPSO for the objective of emission minimization

HPSO (Roy,2021)		TSA	
Corresponding Cost	Optimized Emission	Corresponding Cost	Optimized Emission
48678.04	685.6718	49322.0	685.6328

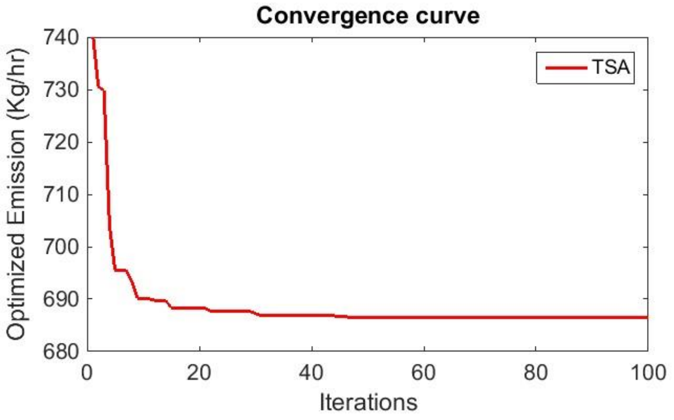

Fig. 3 Convergence curve of TSA for the objective of emission minimization

4.3 Case III (Combined economic & environmental scheduling): Scheduling where both cost and emission are optimized and a comparison table for different methods is given in table-4 mentioning total cost, net emission and power loss.

Table-4 Comparison of result with different methods for multi objectives

Optimized Method	Moghaddam et al. (2011)	Palanichamy and Babu (2008)	Motevasel and Selfi (2014)	Proposed Method
P1 MW	51.8200	51.8200	51.8200	45.41354
P2 MW	32.6500	38.6400	32.6500	29.85926
P3 MW	208.770	248.730	208.780	153.1187
P4 MW	128.120	122.140	128.120	150.6253
P5 MW	292.030	252.020	292.020	261.2053
P6 MW	223.570	223.570	223.570	259.7779
Total Cost $/hr	47549.0	47804.0	47549.0	47088.00
Net Emission Kg/hr	823.350	843.420	823.350	804.3876
Total Loss MW	36.9600	36.9200	36.9600	31.8020

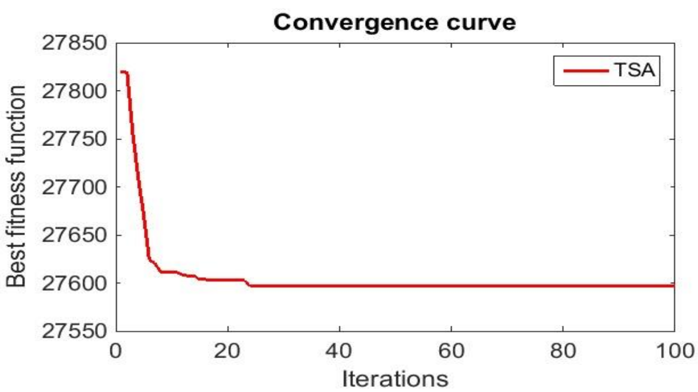

Fig. 4 Convergence curve of TSA for multi objectives

5. Conclusion: This paper proposed economic scheduling, environmental scheduling and combined economic and environmental scheduling using TSA. Superiority of TSA than HPSO and other proposed method has been proved from the obtained result. Demand response and incorporation of renewable source of energy might be extension of this work. Smart microgrid might be formed using this algorithm.

References

Apostolopoulos T. and Vlachos A., 2010, Application of the Firefly Algorithm for Solving the Economic Emissions Load Dispatch Problem, International Journal of Combinatorics, Volume 2011.

Cai J., Ma X., Li Q., Li L. and Peng H., 2010, A multi-objective chaotic ant swarm optimization for environmental/economic dispatch, International Journal of Electrical Power & Energy Systems, Volume 32, Issue 5, 337-344.

Damodaran S. K. and Kumar T. K. S., 2017, Economic and emission generation scheduling of thermal power plant incorporating wind energy, IEEE, 1487-1492.

Kadali K. S.,RajajiL.,Moorthy V. and Viswanatharao J., 2017, Economic generation schedule on thermal power system considering emission using grey wolves optimization, Energy Procedia, Vol 117, 509-518.

Kaur S., Awasthi L. K., Sangal A.L. and Dhiman G., 2020, Tunicate Swarm Algorithm: A new bio-inspired based metaheuristic paradigm for global optimization, Engineering Applications of Artificial Intelligence, Vol 90, 103541.

Roy S.,LahaD., DasA., ChatterjeeS. , Biswas M. , Mandal R. K. & Ghosh B. K., 2021, Application of Multi-Objective Particle Swarm Optimization Technique for Analytical Solution of Economic & Environmental Dispatch.