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Comparative Analysis of Gravitational Search Algorithm and Hybrid PSO-GSA Algorithm for Short Term wind-thermal scheduling in electrical power system

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ABSTRACT

This research papers aims to present the Comparative Analysis of Gravitational Search Algorithm and Hybrid PSO-GSA Algorithm for Short Term wind-thermal scheduling in electrical power system. The use of Wind Power and renewable energy in electric power sector has grown significantly in recent years. The proportion of wind energy in the pattern of world energy has been increasing since the beginning of the twenty-first century. Since wind power plays a positive role in energy saving and reducing emissions of pollutants, power companies should transport and distribute wind power electricity as much as possible. The Effectiveness of Proposed Algorithm is Tested with IEEE Test System Consisting of Three, Six and Fifteen Unit Test System. To achieve the goal of environmental protection, Wind-Power is combined with Thermal power to satisfy time-varying load demand and incorporate transmission losses.

Keywords: Environmental Protection Goal (EPG), Particle Swarm Optimization-Gravitational Search Algorithm(PSO-GSA),, Wind-Thermal Scheduling (WTS).

1. INTRODUCTION

In Modern power system, the proportion of wind energy in the pattern of world energy has been increasing since the beginning of the twenty-first century. Since wind power plays a positive role in energy saving and reducing emissions of pollutants, power companies should transport and distribute wind power electricity as much as possible. Also, the integration of wind-power, natural gas and electricity sectors has sharply increased in the last decade as a consequence of combined cycle thermal power plants. However, when large-scale wind power accesses the power system, the generation scheduling and reserve need to be re-arranged and adjusted due to intermittent and variable characteristic of wind power output. The modern power system around the world has grown in complexity of interconnection and power demand. The focus has shifted towards enhanced performance, increased customer focus, low cost, reliable and clean power. In this changed perspective, scarcity of energy resources, increasing power generation cost, environmental concern necessitates optimal scheduling of power plants. In reality, power stations neither are at equal distances from load nor have similar fuel cost functions. Hence for providing cheaper power, load has to be distributed among various power stations in a way which results in lowest cost for generation. To achieve lowest cost of generation optimal scheduling of generating units is required, which can be achieved by Economic Dispatch and Unit Commitment [10].

2. LITERATURE REVIEW

Researchers in India and abroad have done a lot of work. In the study of optimal scheduling model, in literature [1], a dynamic economic scheduling model is built considering the random variation of the wind speed; and in dynamic optimization model, the unit ramp rate must be a constraint [2]. In the research of unit commitment for power systems with wind farms, the credible data of wind speed and wind power output are needed, in [3], the wind speed is predicted by time series method based on neural network. The optimization of unit scheduling is a large-scale nonlinear mixed integer model, and a variety of algorithms are used to solve the problem. Traditional methods like priority list [4-5], LaGrange Relaxation and dynamic programming have been applied to solve the model. With the development of artificial intelligence algorithms, a variety of intelligent algorithms, such as genetic algorithms [6], ant colony algorithm [7], particle swarm optimization [8-9] have also been used to deal with optimization scheduling. Some important work related to scheduling problem of electric power system is reported below:

Valenzuela J. and Smith A. E. [11] demonstrated that a memetic algorithm (MA) combined with Lagrangian relaxation (LR) can be very efficiently used for solving large unit commitment problems. Mafteiu L. O. and Mafteiu-Scai E. J. [12] developed a memetic algorithm (MA) for the solution of linear system of equations by converting into an optimization problem. Mafteiu-Scai L. O. [13] proposed a technique using memetic algorithm (MA) for the improvement of convergence of iterative methods to solve linear or nonlinear systems of equations. Sanusi H. A.et al. [14] investigated the performance of GA and MA for a constrained optimization and found that MA converges quicker than GA and produces more optimal results but the time taken by iteration in GA is less than that in MA. Yare Y. et al.[15] proposed the differential evolution (DE) approach for generator maintenance scheduling (GMS) and economic dispatch (ED) of the Indonesian power system to optimize the cost of operation of 19 units.

Chakraborty S.et al. [16] presented a fuzzy modified differential evolution approach for solving thermal UC problem integrated with wind power system. Sharma R.et al. [17] developed a new method to solve the economic dispatch (ED) problem known as Self-Realized Differential Evolution which was tested for 40- unit system and 10- unit system. Hardiansyahet al. [18] investigated the features of artificial bee colony algorithm (ABC), differential evolution (DE) algorithm and particle swarm optimization (PSO) for 3 and 6-unit systems and found that differential evolution algorithm converges faster than artificial bee colony algorithm and particle swarm optimization. Ravi C.N. and Rajan C. C. A. [19] used differential evolution (DE) optimization algorithm to solve optimal power flow (OPF) problem considering IEEE 30 bus standard power system. Lee K. S. and Geem Z. W. [20] developed a new Harmony search (HS) algorithm for global ooptimization. Coelho L.S. and Mariani V.C. [21] improved the established harmony search (HS) algorithm using exponential distribution for a 13- unit system.

Coelho L.S.et al. [22] proposed a customized harmony search algorithm with differential evolution (DE) and chaotic sequences, CHSDE algorithm, for solving the ELD problemfor a 10- unit system. Tuo S. and Yong L. [23] presented an enhanced harmony search with chaos (HSCH). The test results show that the HSCH algorithm is a convincing algorithm and it is much better than the classical HS technique and harmony search algorithm with differential evolution (HSDE). Shukla S. and Anand A. [24] applied harmony search technique for the multi-objective optimization of a styrene reactor. Arul R.et al. [25] applied harmony search algorithm to solve ELD problem with transmission losses under the changing patterns of consumer load for standard 6-bus system, standard IEEE-14 bus system, and the standard IEEE-30 bus system.

Xue-hui L.et al. [26] adopted a meta-heuristic algorithm, the shuffled frog-leaping algorithm (SFLA) and applied to solve travelling salesman problem. Reddy A. S. and Vaisakh K. [27] customized the shuffled frog-leaping algorithm into a modified shuffled frog- leaping algorithm (MSFLA) for solving the economic emission load dispatch problem for IEEE- 30 bus system. Pourmahmood M.et al. [28] also proposed a modified shuffled frog- leaping (MSFL) algorithm. Jebaraj L.et al. [29] applied SFLA to optimize the location and the size of the two FACTS devices, TCSC and SVC, for IEEE 30- bus system under certain considered conditions.Anita J. M. and Raglend I. J. [30] presented the application of SFLA optimization algorithm to find the solution of UCP to a 10- unit thermal system.

Fang H., et al. [31] presented a new snake algorithm which is demonstrated to overcome the drawbacks of traditional snake/ contour algorithms for contour tracking of multiple objects more effectively and efficiently. The experimental results of the tests carried out have proved that the proposed method is robust, effective and accurate in terms of finding the boundary solutions of multiple objects. Simon D. [32] developed biogeography-based optimization (BBO) algorithm and tested for 14 benchmark functions using BBO and compared the results with GA, PSO, DE, ES, stud genetic algorithm (SGA), PBIL and ACO. Kamboj V.K. and Bath S.K.[33] applied biogeography-based optimization (BBO) for the solution of economic load dispatch problem of electric power system and specified the scope of BBO for Multi-Objective Scheduling problem.

A survey of existing literature on the problem reveals that various numerical optimization and mathematical programming based optimization techniques have been applied to solve Economic Load Dispatch and Hydro-Thermal Scheduling problem and some of them are applied to wind-thermal scheduling problem. Most of these are calculus-based optimization algorithms that are based on successive linearization and use the first and second order differentiations of objective function and its constraints equations as the search direction. They usually require heat input, power output characteristics of generators to be of monotonically increasing nature or of piecewise linearity thus resulting in an inaccurate dispatch and scheduling.

Also, very few work is done to solve the combined wind-thermal generation scheduling problem, which is a mixture of conventional and Non-Conventional Generating Units. Therefore to overcome the above mentioned limitations, research proposal here is to explore and present Short-Term Wind-Thermal Scheduling of Electric power System using hybrid PSO-GSA Algorithm. Also, Environment protection is most important for safe and economic operations of electric power system. To achieve such eco-friendly environment goal, research proposal for wind-thermal scheduling problem of electric power system using hybrid PSO-GSA has been undertaken.

3. MATHEMATICAL FORMULATION

The classical formulation of the standard Wind-Thermal Scheduling problem is an optimization problem of determining the schedule of the fuel costs of real power outputs of generating units subject to the real power balanced with the total load demand, subtracting the Wind-Power from the total Generation of Thermal Generating Units, as well as the limits on generators outputs. In mathematical terms the Wind-Thermal Scheduling problem objective function can be defined as following:

$$\min[FC(P_n)] = \sum_{n=1}^{U}(C_{0n}P_n^{\,2} + C_{1n}P_n + C_{2n}) \quad \text{Rs./Hour} \tag{1}$$

subject to below mentioned constraints:

(i) The energy balance constraints:

$$\sum_{n=1}^{U} P_n = P_{Demand} + P_{Loss} - P_{Wind} \tag{2}$$

(ii) The inequality constraints:

$$P_n^{\min} \le P_n \le P_n^{\max} \qquad (\mathrm{n} = 1, 2, 3, \ldots\ldots\ldots\ldots, \mathrm{U}). \tag{3}$$

The most simple and approximate method of expressing power transmission loss, P_{Loss} as a function of generator powers using B-coefficients and mathematically can be expressed as:

$$P_{Loss} = \sum_{n=1}^{U}\sum_{m=1}^{U} P_{g_n} B_{nm} P_{g_m} \quad \text{MW.} \tag{4}$$

The constrained Wind-Thermal Scheduling Problem can be converted to unconstrained Wind-Thermal Scheduling Problem using Penalty of definite value, which can be mathematically expressed as:

$$\min[\mathrm{FC}(\mathrm{P_n})] = \sum_{n=1}^{U} \mathrm{F_n}(\mathrm{P_n}) + 1000 * \mathrm{abs}(\sum_{n=1}^{U} \mathrm{P_n} - \mathrm{P_{Demand}} + \mathrm{P_{wind}} - \sum_{n=1}^{U}\sum_{m=1}^{U} \mathrm{B_{nm}P_nP_m}) \tag{5}$$

4. Hybrid PSO-GSA ALGORITHM FOR WIND THERMAL SCHEDULING

Rashedi et. al. proposed one of the newest heuristic algorithms, namely Gravitational Search Algorithm (GSA) in 2009. GSA is based on the physical law of gravity and the law of motion [35,36]. The gravitational force between two particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them [34]. GSA a set of agents called masses has been proposed to find the optimum solution by simulation of Newtonian laws of gravity and motion [35]. In the GSA, consider a system with m masses in which position of i^{th} mass is defined as follows:

$$X_i = \left(x_i^1, \ldots, x_i^d, \ldots, x_i^n\right), \quad i = 1, 2, \ldots, m \tag{6}$$

where xi^d is position of the i^{th} mass in the d^{th} dimension and n is dimension of the search space. At the specific time 't' a gravitational force from mass 'j' acts on mass 'i', and is defined as follows [34, 36]:

$$F_{ij}^d(t) = G(t)\frac{M_{pi}(t) x M_{aj}(t)}{R_{ij}(t) + \varepsilon}\left(x_j^d(t) - x_i^d(t)\right) \tag{7}$$

where M_i is the mass of the object i, M_j is the mass of the object j, G(t) is the gravitational constant at time t, R_{ij} (t) is the Euclidian distance between the two objects i and j, and ε is a small constant.
The total force acting on agent i in the dimension d is calculated as follows:

$$F_i^d(t) = \sum_{j=i,\ j\neq i}^{m} rand_j F_{ij}^d(t) \quad (8)$$

Where, $rand_j$ is a random number in the interval [0,1]. According to the law of motion, the acceleration of the agent i, at time t, in the d^{th} dimension, $ai^d(t)$ is given as follows:

$$a_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \quad (9)$$

Furthermore, the next velocity of an agent is a function of its current velocity added to its current acceleration. Therefore, the next position and the next velocity of an agent can be calculated as follows [36]:

$$v_i^d(t+1) = rand_i \, x \, v_i^d(t) + a_i^d(t) \quad (10)$$

$$x_i^d(t+1) = x_i^d(t) + v_i^d(t+1) \quad (11)$$

Where, r and $_i$ is a uniform random variable in the interval [0, 1]. The gravitational constant, G, is initialized at the beginning and will be decreased with time to control the search accuracy. In other words, G is a function of the initial value (G0) and time (t):

$$G(t) = G(G_0, t) \quad (12)$$

$$G(t) = G_0 e^{-\alpha \frac{t}{T}} \quad (13)$$

The masses of the agents are calculated using fitness evaluation. A heavier mass means a more efficient agent. This means that better agents have higher attractions and moves more slowly. Supposing the equality of the gravitational and inertia mass, the values of masses is calculated using the map of fitness. The gravitational and inertial masses are updating by the following equations [34,36]:

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - worst(t)} \quad (14)$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{m} m_j(t)} \quad (15)$$

where $fit_i(t)$ represents the fitness value of the agent i at time t, and the best(t) and worst(t) in the population respectively indicate the strongest and the weakest agent according to their fitness route. For a minimization problem:

$$best(t) = \min_{j\in\{1,\dots,m\}} fit_j(t) \quad (16)$$

$$worst(t) = \max_{j\in\{1,\dots,m\}} fit_j(t) \quad (17)$$

ALGORITHM AND FLOW CHART FOR PROPOSED HYBRID PSO-GSA

The proposed GSA approach for short-term wind thermal problem can be summarized as follows:

Step 1. Identify Search space.

Step 2. Generate initial population between minimum and maximum values.

Step 3. Evaluate Fitness function considering wind power agents.

Step 4. Update *G(t), best(t), worst(t)* and $M_i(t)$ *for* $i = 1,2,\ldots,m$.

Step 5. Calculation of the total force in different directions.

Step 6. Calculation of acceleration and velocity using equation (11) and (6) respectively.

Step 7. Updating agents' position using equation(6).

Step 8. Repeat step 3 to step 7 until the stop criteria is reached.

Step 9. Stop.

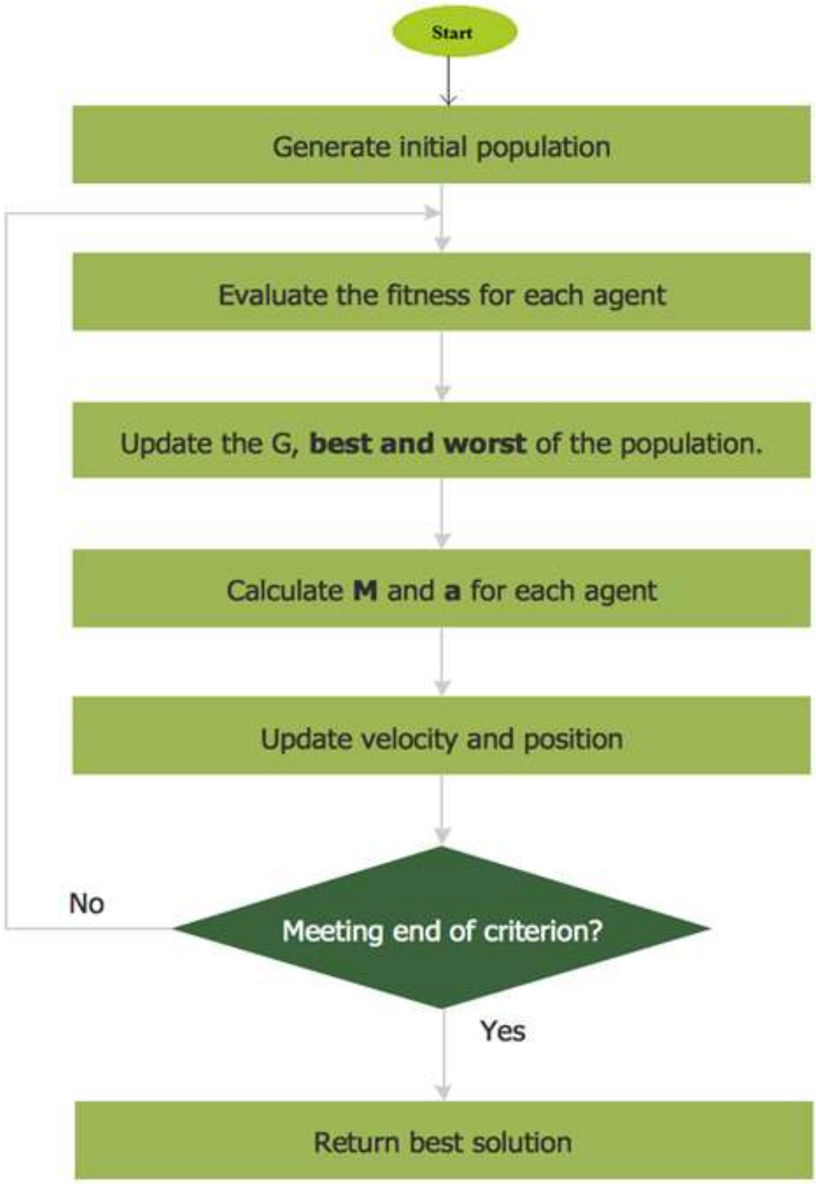

Fig.1: Flow Chart of Hybrid PSO-GSA Algorithm for Wind-Thermal Scheduling

5. TEST SYSTEMS AND SIMULATION DATA

In order to verify the feasibility and efficiency of the proposed algorithm for wind-thermal scheduling problem, the algorithm was tested three test cases considering loss coefficients for calculation of Transmission losses. The test System Consist of 3, 6 and 15 Generating Units. The valve point effect is ignored for thermal generating units, while considering wind power for generation scheduling problem. The proposed algorithm is executed with following parameters: m=40 (masses), G is set using Eq.(12) and (13). where G_0 is set to 100 and α is set to 10, and T is the total number of iterations. Maximum iteration numbers are 250 for these case studies.

Test System-I: This test case study considered of three thermal units of generation without effects of valve-point as given Table I. The Loss coefficients matrices given in Table-II are used to calculate the transmission losses. In this case, the load demand is considered for short duration of 8 hours. Wind farm and this system is generalized from a certain region power system in North Korea.

Table-I: Test data for Three Generating Unit System

C0	C1	C2	P_{min}	P_{max}
0.00482	7.97	78	50	200
0.00194	7.85	310	100	400
0.001562	7.92	562	100	600

Table-II: Loss Coefficient Matrices

B	0.000676	0.0000953	-0.0000507
	0.0000953	0.000521	0.0000901
	-0.0000507	0.0000901	0.000294
B0	-0.00766	-0.00342	0.0189
B0	0.40357		

Test System-II: This test case study considered of six thermal units of generation without effects of valve-point as given Table III. The Loss coefficients matrices given in Table-IV are used to calculate the transmission losses. In this case, the load demand is considered for short duration of 8 hours. Wind farm and this system is generalized from a certain region power system in South China.

Table-III: Test data for Six-Generating Unit System

C0	C1	C2	P_{min}	P_{max}
0.007	7	240	100	500
0.0095	10	200	50	200
0.009	8.5	220	80	300
0.009	11	200	50	150
0.008	10.5	220	50	200
0.0075	12	190	50	120

Table-IV: Loss Coefficient Matrices for 6-unit test system

B	0.000017	0.000012	0.00007	-0.00001	-0.000005	0.000002
	0.000012	0.000014	0.000009	0.000001	-0.000006	0.000001
	0.000007	0.000009	0.000031	0	-0.00001	0.000006
	-0.000001	0.000001	0.0000	0.00024	-0.000006	0.000008
	-0.000005	-0.000006	-0.00001	-0.000006	0.000129	0.000002
	-0.000002	-0.000001	-0.000006	-0.00008	-0.000002	0.00015
B0	-0.3908	-1.29	7.047	0.591	2.161	-6.63
B00	0.0056					

Test System-III: This test case study considered of fifteen thermal units of generation without effects of valve-point as given Table V. The Loss coefficients matrices given in Table-VI are used to calculate the transmission losses. In this case, the load demand is considered for short duration of 12 hours. Wind farm and this system is generalized from a certain region power system in North Korea.

Table-V: Test data for 15-Generating Unit System

C0	C1	C2	P_{min}	P_{max}
0.000299	10.1	671	150	455
0.000183	10.2	574	150	455
0.001126	8.8	374	20	130
0.001126	8.8	374	20	130
0.000205	10.4	461	150	470
0.000301	10.1	630	135	460
0.000364	9.8	548	135	465
0.000338	11.2	227	60	300
0.000807	11.2	173	25	162
0.001203	10.7	175	25	160
0.003586	10.2	186	20	80
0.005513	9.9	230	20	80
0.000371	13.1	225	25	85
0.001929	12.1	309	15	55
0.004447	12.4	323	15	55

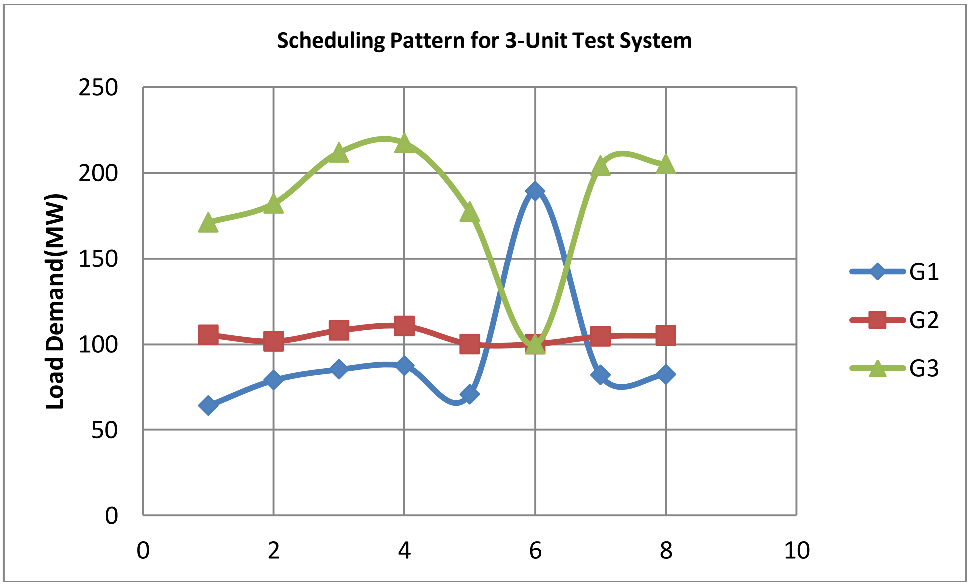

Fig. 2 : Scheduling Pattern for 3- Units System

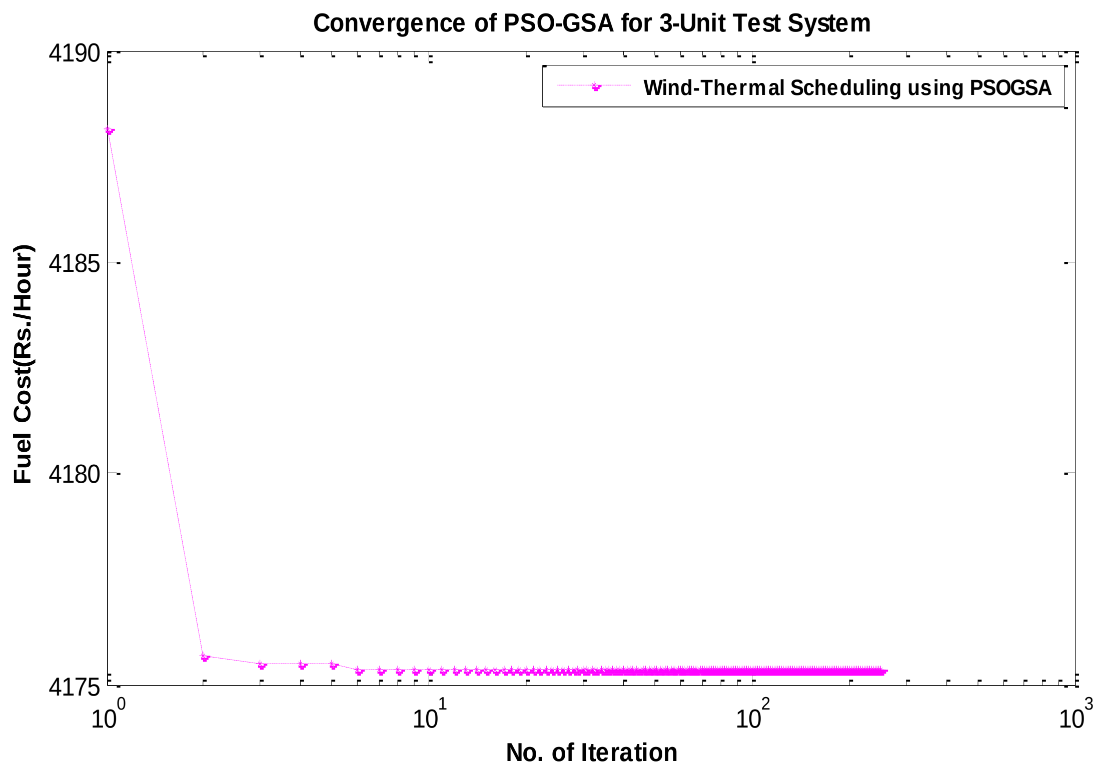

Fig. 3 : Convergence of PSO-GSA for 3- Units System

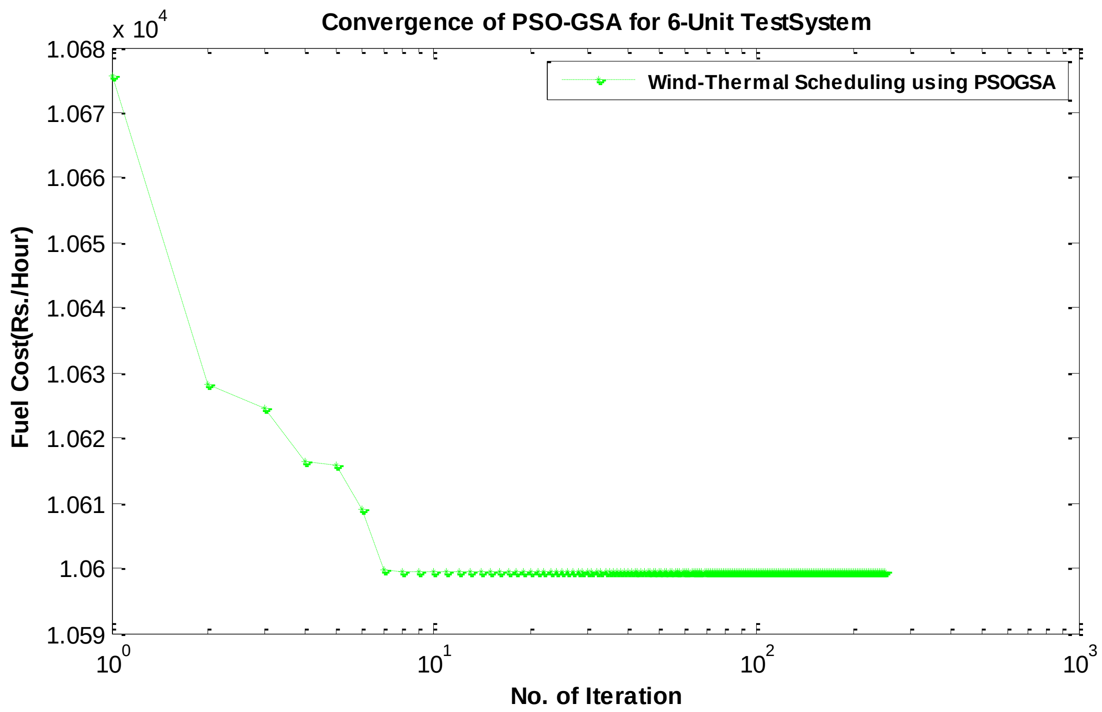

Fig. 4 : Convergence of PSO-GSA for 6-generating unit system

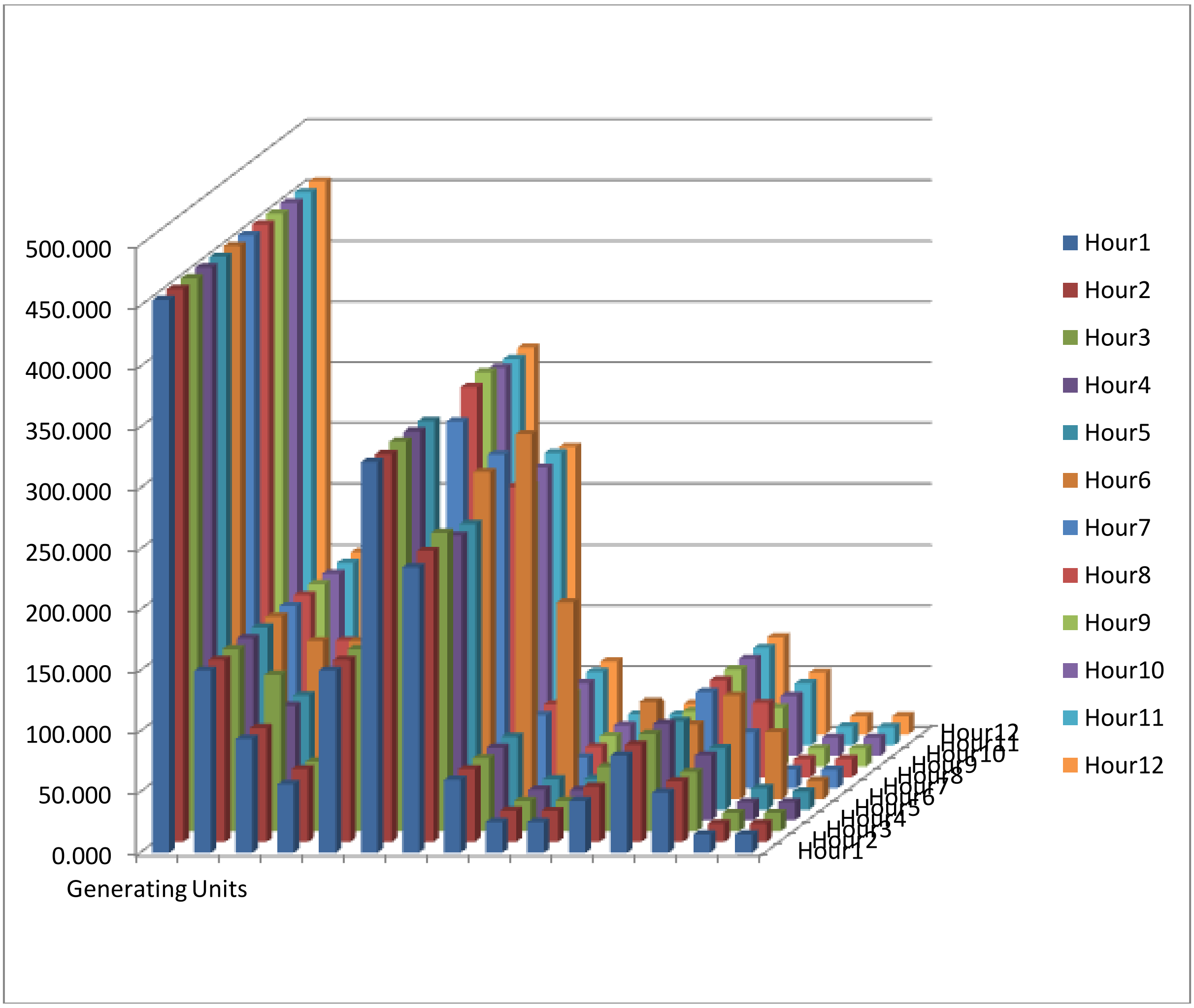

Fig. 5: Distribution of Load Among various Units for 15-Unit Test system

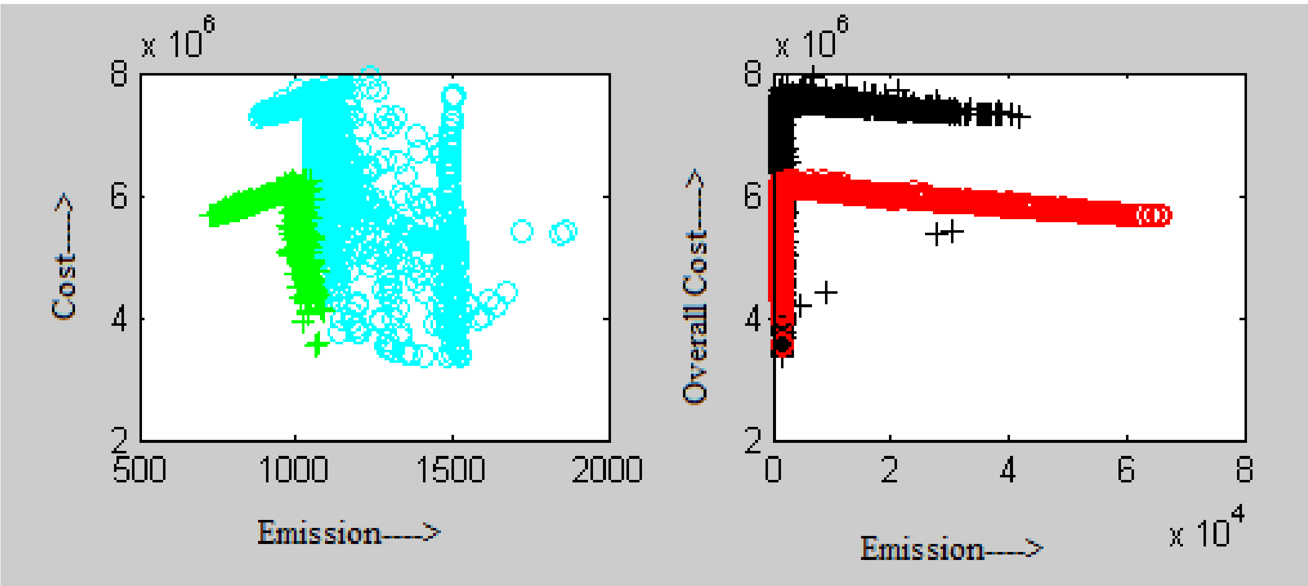

Fig. 6: Comparison of Results for 30-Bus System for GSA and PSO-GSA

CONCLUSION

In this paper, the test system contains 3, 6 and 15 thermal generating units and three wind farms and the test systems are generalized from a certain region power system. The scheduling period for 3 and 6 units system is divided into 8 hours and for 15 units test system, it is divided into 12 hours. The operating parameters of thermal units are listed in Table-I, II, III, IV, V and VI and the load demand and the wind power output predicted. The MATLAB simulation software is used to obtain the corresponding results. It has been found that optimal fuel cost for three generating unit test system is Rs. 32607.4217 and power Loss is 214.7802 MW. The optimal fuel cost for six generating unit test system is Rs. 158955.7171 and power Loss is 171.6144939 MW.

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