World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.924

ECONOMIC LOAD DISPATCH OF INTEGRATION OF PV WITH THERMAL GENERATION – A COMPARISON OF SOLVER WITH MOTH FLAME ALGORITHM

***Sridevi Pusapati and Dr. B. Ravindranath Reddy**

[1]Research Scholar, JNTUH, Hyderabad, India.

[2]Dy. Executive Engineer, JNTUH, Hyderabad, India.

Article Received on 04/06/2021 **Article Revised on 24/06/2021** **Article Accepted on 14/07/2021**

***Corresponding Author**
Sridevi Pusapati
Research Scholar, JNTUH, Hyderabad, India.

ABSTRACT

In this paper, economic load dispatch problem considering Hybrid power system using Moth flame algorithm is discussed. Load Dispatch is the allocation of the load demand to the various interconnected generating units considering their various constraints so as to obtain the most economical operating costs. Conventional sources like coal in Thermal Power plant is fast depleting, its cost of operation is more and also each generating unit usually has a unique cost-per-hour characteristic .There is a vast scope of the solar power generation in India due to the high solar irradiance index and the cost of operation of is less. The problem of ELD with the inclusion of the renewable power sources will reduce the load of generation on the thermal units. Hence here 6 Thermal units are considered along with 4solar (PV) units. In this paper Moth Flame Algorithm (MFA) is used as it is robust and requires only few control variables to regulate and works best in exploration and exploitation of the search space effectively and efficiently. The results are compared with GRG algorithm in Solver tool of Excel, by considering the fuel cost coefficients and emission penalty constants of thermal power plants and the factor of overestimation, underestimation of available solar power. It is observed that as the number of PV units are increased the cost of load dispatch is decreased and the Moth Flame Algorithm used can get the solution to the problem in a fast and economical way compared to Solver.

KEYWORDS: Load Dispatch, Photo-voltaic, Fuel cost coefficients, Swarm Intelligence, Bio inspired Algorithms.

INTRODUCTION

Due to massive increase in demand of electricity, energy crisis has reached to its maximum degree all over the world in previous ten years. In today's world the most difficult and important part is the interconnection of large generators in parallel in order to run them economically and to full fill the load demands. Multiple number of generating units are connected and synchronized in parallel in order to ensure the proper working of large amount of load connected to the system These generators are connected to each other through a common copper bus bar. The primary objective of multiple generating units is to make sure safe and reliable working of the power system while keeping the operating and fuel cost of generating units to the minimum level possible. For this reason, optimized and timely switching of generating units is made possible to ensure maximum cost savings without affecting the load. Also, there is a vast scope of the solar power generation in India due to the high solar irradiance index and free availability. Hence in this paper, IEEE -30 bus system consisting of 6 thermal units are considered along with 22KW 44KW and 66 KW rating PV units placed at various locations like Hyderabad, Kothagudem and Warangal to analyse the change in the cost of load dispatch with various combination of units at 1000MW, 1200MW and 1400MW loads. The problem of economic load dispatch with the inclusion of the renewable power sources will reduce the load of generation on the thermal units and other fossil fuel units, conserves the coal and decreases the pollution caused by emissions in thermal power plant.Here we are including Photo Voltaic System (PVS) in consortium with thermal power generation units.

The input output characteristic curves of all the connected generators is not same and identical to each other, so the load cannot be symmetrically divided on all the generators connected in parallel. All or most of the generators connected are of different brands, having variable efficiency and dissimilar input output characteristics. All these generators will also have different fuel cost curves at different power outputs. It increases the need of ELD to vary the power of generating units within the desired generating limits of each individual generator to meet output power demand within optimal fuel cost. Economic load dispatch is conducted to compute the operating cost of Hybrid power system through the strategic dispatch of electricity while fulfilling load demand. In this research, economic dispatch is conducted on 6 thermal units in combination with 4 photovoltaic units.

A number of Modern BIA (Biologically Inspired Algorithms) find their applications to solve ELD. The **Evolutionary based algorithms** aim at benefiting from collective phenomena in adaptive populations of problem solvers utilizing the iterative progress comprising growth, development, reproduction, selection, and survival as seen in a population. EAs are the most well-known, classical and established algorithms among nature inspired algorithms, which is based on the biological evolution in nature that is being responsible for the design of all living beings on earth, and for the strategies they use to interact with each other. EAs employ this powerful design philosophy to find solutions to hard problems. EAs are non-deterministic algorithms or cost based optimization algorithms. A family of EAs comprises of genetic algorithm (GA), genetic programming (GP), Differential Evolution, evolutionary strategy (ES) and Paddy Field Algorithm. The members of the EA family share a great number of features in common. They are all population-based stochastic search algorithms performing with best-to-survive criteria. Each algorithm commences by creating an initial population of feasible solutions, and evolves iteratively from generation to generation towards a best solution. In such optimization successive iterations of the algorithm, fitness-based selection takes place within the population of solutions. Better solutions are preferentially selected for survival into the next generation of solutions.

The **Ecology based Algorithms** are also bio inspired algorithms comprising of the living organisms along with the abiotic environment with which organisms interact such as air, soil, water etc. There can be numerous and complex types of interactions among the species of ecosystem which can occur between the species or within the species. The nature of these interactions can be cooperative or competitive. The family of these include PS2O, Invasive weed colony Algorithm (IWCA), Biogeography based Optimization (BBO).

Swarm based Algorithms are also bio inspired and are an extension of EC. While EAs are based on **genetic adaptation** of organisms, Swarm Intelligence (**SI**) is based on collective **social behavior** of organisms based on their irregular movements in the problem space**. SI** encompasses the implementation of collective intelligence of groups of simple agents that are based on the behavior of real-world insect swarms, as a problem-solving tool. The family of SI which can solve ELD problem comprises of Particle swarm optimization (PSO), Ant colony optimization(ACO),Artificial Bee colony optimization(ABC), Fish Swarm optimization(FSO), Intelligent Water Drops optimization(IWDO), Bat Algorithm(BA), Krill - Herd Algorithm(KHA), Bacterial Foraging Optimization Algorithm(BFOA), Firefly Algorithm (FFA), Artificial Immune system Algorithm(AISA), Group research Algorithm (GRA), Shuffled Frog Leap Algorithm(SFLA) etc.

Economic load dispatch involves computing the suitable generation level, and the resulting operating cost. Solar power can be forecasted and integrated into the Grid (e.g., GE Energy, 2008). According to "A Survey of Bio inspired Optimization Algorithms 'by Binitha S, S Siva Sathya, (IJSCE,May2012), Swarm intelligence technique is based on collective social behaviour of organisms and it deals with the implementation of collective intelligence of groups of simple agents like bees, ants, krills, swarms etc as a problem solving tool. According to "Optimizing Economic Load Dispatch with Renewable Energy Sources via Differential Evolution Immunized Ant Colony Optimization Technique" by N. A. Rahmat#, N. F. A. Aziz et al (2017), (ELD) is computed to analyse the operating cost of 7Thermal power integrated to 2PV power system and could arrive at a conclusion that by integrating Thermal with PV units decreases the cost of operation as well as the losses. In this thesis 6 thermal units are integrated with 2PVunits, 4 PV units & 6PV units for 1000MW load, 1200MW load and 1400MW load separately and also when placed at various locations and the cost of load dispatch is solved using GRG algorithm a solver add-in in Excel and also by using Fire fly Algorithm executed in JAVA programming and the results are compared with respect to the speed in execution and economy. **Solver** an **add**-in program is used for what-if analysis and to find an optimal (maximum or minimum) value for a formula in the objective cell in Excel — subject to constraints, or limits, on the values of other formula cells on any worksheet.

Methodology: Economic Load Dispatch of Thermal Energy interconnected with Solar energy:

Economic load dispatch is calculated to find out the operating cost of power system through the strategic Dispatch (unit commitment) of various generating units while fulfilling load demand considering emissions, penalty constraint, prohibited operating zones, ramp-rates, valve-point loading effects. and Transmission line losses for thermal power units and considering the operating costs, the reserve cost factor and penalty cost factor for overestimation and underestimation of available solar power for PV units respectively.

Transmission line losses are negligible for PV as PV units are considered to be distributed near the load end.

In general only real power generated is considered for solving ELD.

Operating Cost equation of Thermal power plant

The equivalent cost of the generator includes mainly the fuel cost, labour cost and maintenance cost etc. The cost depends on the requirement of output power. The quadratic fuel cost function can be given as:

$$Cost_{gen} = \sum_{i=1}^{n} C_i\, P_i = \sum_{i=1}^{n} a_i\, P_i^2 + b_i\, P_i + c_i \quad ....(1)$$

Where *Ci* is the fuel cost of generating *Pi* amount of output power. *ai*, *bi* and *ci* is the fuel cost coefficient for *Pi*.

a_i=constant coefficient measure of losses in the ith generator.

b_i = constant coefficient represents the fuel cost in the ith generator.

c_i = constant coefficient includes salary and wages, interest and depreciation of the ith generators.

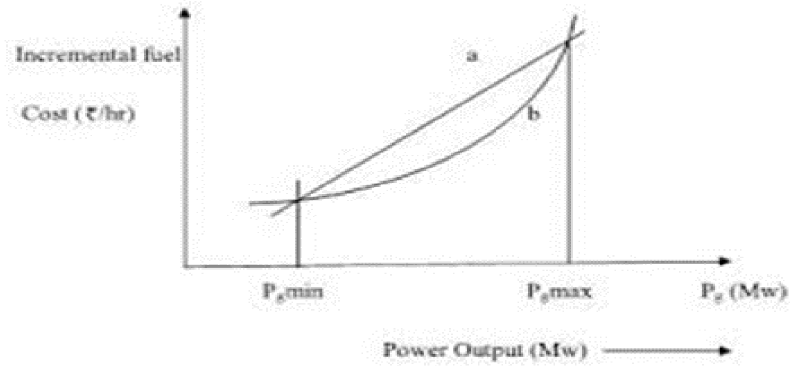

Fig. 1: Cost function curve of Thermal power plant.

Considering the effect of valve point loading, which produces rippling effect because of variation in speed of the turbine due the effect of steam admission through various nozzles which inturn depends on the power to be generated by a particular unit, P_i.

$$Cost_{gen} = \sum_{i=1}^{n} C_i\, P_i = \sum_{i=1}^{n} a_i\, P_i^2 + b_i\, P_i + c_i + \left| d_i \sin(e_i\,(p_i^{min} - p_i)) \right| ...(2)$$

Where d_i and e_i are the coeffients reflecting valve point loading of ith generator.

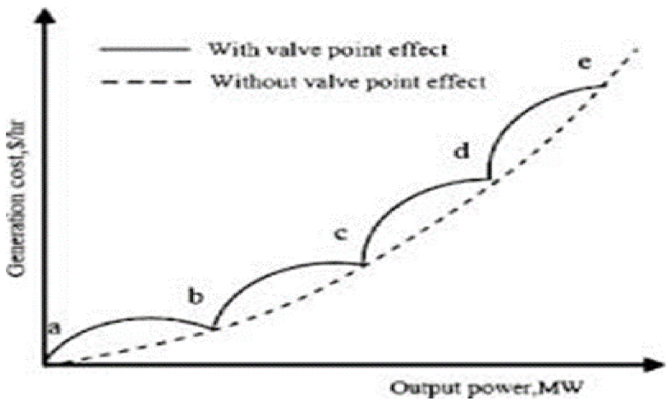

Fig. 2: Operating cost curve considering valve point loading effect.

The losses in the transmission network can be calculated using the formula

$$P_{loss} = \sum_i^n \sum_j^n P_i B_{ij} P_j + \sum_i^n B_{0i} P_i + B_{00} \quad .....(3)$$

Where B_{ij}, B_{0i}, and B_{00} are the elements of loss coefficient matrix.

2.1.4 The total Real power to be generated is given by Real power Loss constraint

$$P_{T\,total} = \sum_{i=1}^{N_g} P_i = P_D + P_{loss} \quad ......(4)$$

The total generated power by Thermal units must be equal to the summation of load demand, P_D and power loss, P_{loss} as in Eq. (4)

The inequality constraint of generation limits for each unit is given by Eq.(5)

$$P_{imin} \leq P_i \leq P_{imax} \quad .... (5)$$

Where *Pimin* and *Pimax* is the minimum and maximum generation limits of i^th generator respectively.

The emission dispatch involves generation of required power for serving the system load with minimum emissions in the form of COX, SOX and NOX to the atmosphere.The emission dispatch function for a particular power generation is given by.

$$Emission\ Cost = \sum_{i=1}^{n} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \quad .....(8)$$

Where αi, βi, γi are coefficient of emission of the ith generating unit

The Objective function considering valve point loading and emission is given as Min

$$Cost_{gen}) = Min\ (\sum_{i=1}^{n}((a_i P_i^2 + b_i P_i + c_i + | d_i \sin(e_i (p_i^{min} - p_i) | + h_i(\alpha_i P_i^2 + \beta_i P_i + \gamma_i))) \quad ...(9)$$

Where $h_i = \frac{a_i P_{imax}^2 + b_i P_{i\,max} + c_i}{\alpha_i P_{imax}^2 + \beta_i P_{imax} + \gamma_i}$ **.....(10)**

Where P_{imax} is the maximum generation limit of i^{th} generator

h_i is the price penalty function for emissions for i^{th} generator.

h_i for a particular load demand is obtained by calculating the value of h_i for each generating unit, arranging these values $of\ h_i$ in assending order along with the corresponding P_{max} of the units and finding the cumulative values of maximum power generation. The value of h_i for a particular load demand is the value of h_i corresponding to the cumulative P_{max}.

2.2 The operating cost of each PV unit is given by

Considering the placement of 22KW, 44 KW & 66KW PV units in the regions of Hyderabad (17.35^0 N, 78.45^{0}E), Warangal (17.95^{0}N, 79.65^{0}E), Kothagudem (17.55^{0}N, 80.65^{0}E), the average output power of the units is calculated based on the solar radiance values of every month.[9] The transmission line losses are not considered as the solar (PV) units are placed at the load end.

The expected solar output power of i th unit is given by

$P(PV_i) = P(PV_{io}) * f_b(S_i)$ .....(11)

Where $f_b(S_i)$ is the beta distribution function to find the distribution of solar radiance across the panel.

PV_{io} is the power generation of panel

$PV_{io} = N * FF * V_y I_y$ .....(12)

where N is the total number of PV modules.

FF is the fill factor

V_y and I_y are calculated from the open circuit and short circuit

Characteristics of PV cell at ambient temperatures.

$Cost(PV_{ij}) = C_{pvi}(pv_{ij}) + C_{p.pvi}(PV_{i.av} - pv_{ij}) + C_{rpvi}(pv_{ij} - PV_{av})$ ....(13)

Where the first part is the weighted cost function of PV per unit based on the solar irradiance and C_{pvi} is the cost coefficient , the second part is the penalty cost for not using all the available PV generated power and $C_{p,pvi}$ is the penalty cost coefficient for under estimation of power, and the third part is the penalty cost on the reserves which is due to that the actual solar power generated is less than the scheduled power and $C_{r,pvi}$ is the reserve cost coefficient for over estimation of PV power. *pvij* is the power committed by *ith* PV unit during *jth* hour. *PVi,av* is the available amount of energy of *ith* PV unit, adding the factor of overestimation and underestimation of available solar power.

The direct cost coefficient of solar power, penalty cost coefficient and reserve cost coefficient for the solar power are 7.86 Rs/KW, 17.80Rs/KWh and 12.28 Rs/KWh respectively. A proper estimation of solar probability density function should be made to determine actual probability of solar power generation. This is obtained from the solar radiance values at various locations during various seasons as given by NREL,[9]

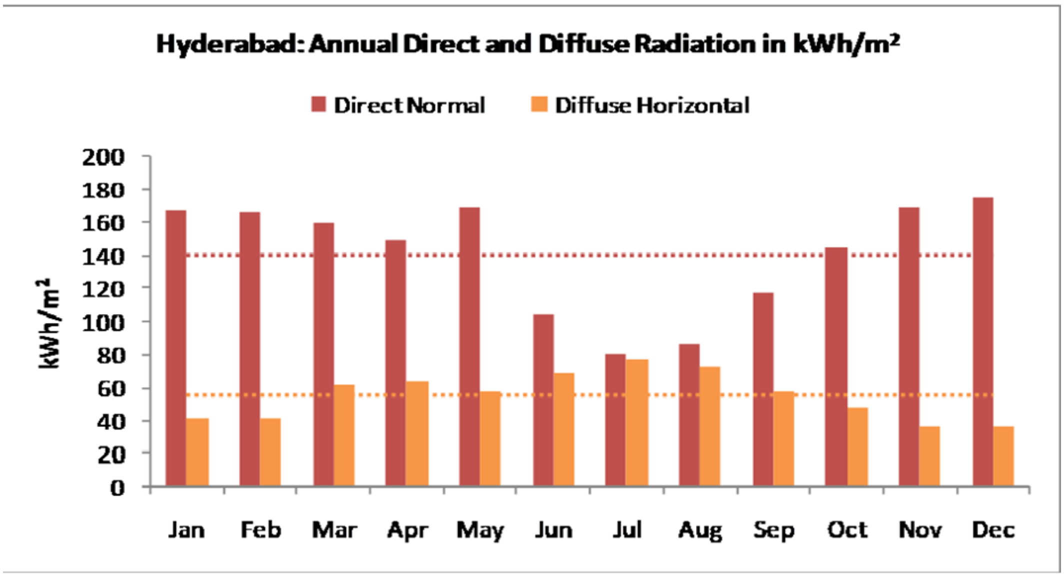

Fig. 3: Annual Solar Irradiance in Hyderabad in KWh/ m^2.

2.3 The Objective Function

The objective function of this study is to minimize the operating cost of power system when PV units are used along with Thermal units for Economic distribution of load among the units.

The total operating cost of conventional generators and PV units is calculated by combining Eq. (1) and eq. (5),

Cost $_{total} = \sum_{i=1}^{n}(C_i P_i) + \sum_{i=1}^{m} cost(PV_{ij})$ ……………(14)

The Equation (14) is evaluated considering the fuel co-efficients and minimum and maximum loading capacities for thermal units and the various cost co-efficients and minimum, maximum and average capacities of Solar PV units.

2.4 Solver Add-in in Excel

Excel Solver has a special set of commands to support What-if Analysis Tools. It's primary purpose is for simulation and optimization of various business and engineering models. It is helpful when dealing with all kinds of optimization problems where best decision is needed. It is used to find the optimal value i.e., the most economical value of cost function such that the load scheduling meets the load demand. The Excel solver algorithm used is **GRG non linear Algorithm**. It is used for non-smooth problems, which are the most difficult type of optimization problems.

The various solver parameters like cost coefficients, emission coefficients minimum, maximum values and the constraints of thermal power plant; The minimum, maximum, average values, the cost coefficients of PV units are placed in a spread sheet. The optimum (minimum) value of cost is set as objective of the system, the load scheduling for various units will be the changing variable cells which in turn is equal to the load demand. The cost of power plants are subjected to the constraints which can be defined in the algorithm. The GRG Nonlinear Algorithm in solver is used to solve ELD. **GRG** stands for "Generalized Reduced Gradient". This **solver** method looks at the gradient or slope of the objective function as the input values (or decision variables) change and determines that it has reached an optimum solution when the partial derivatives equal zero. It gives the solution at a very fast rate.

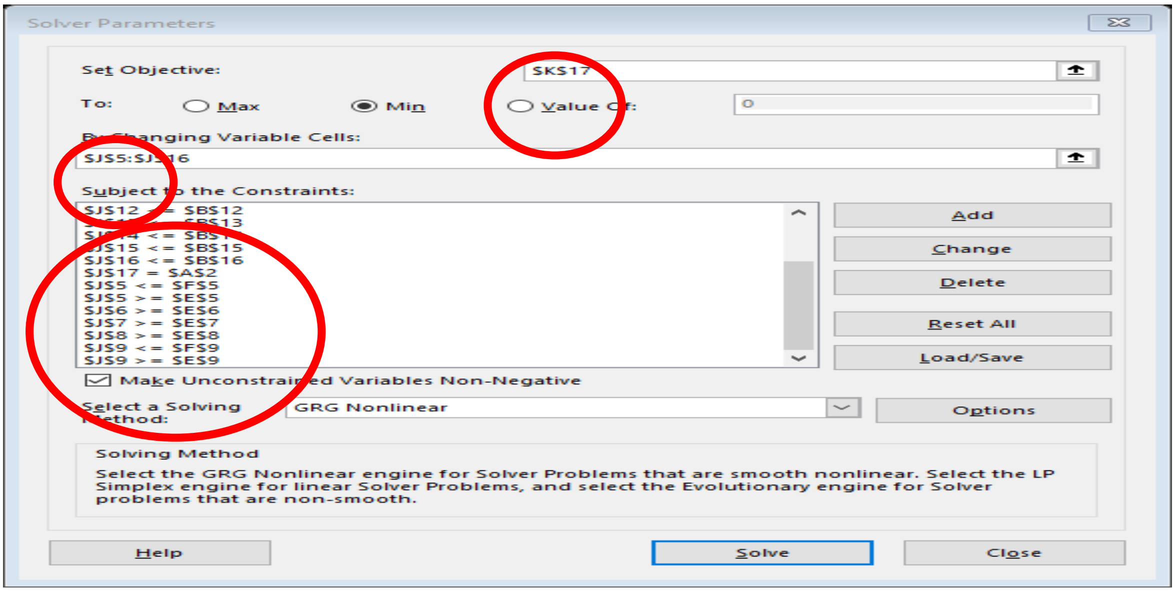

Fig. 4: The screen shot of solver configuration.

2.5 Moth Flame Algorithm

Moths are fancy insects, which are similar to the family of butterflies. Basically, They have two main milestones in their lifetime: larvae and adult. The larvae is converted to moth by cocoons. The most interesting fact about moths is their special navigation methods in night. They have been evolved to fly in night using the moon light. They utilized a mechanism called transverse orientation for navigation. In this method, a moth flies by maintaining a fixed angle with respect to the moon, a very effective mechanism for travelling long distances in a straight path. Since the moon is far away from the moth, this mechanism guarantees flying in straight line. When moths see a artificial light, they try to maintain a similar angle with the light to fly in straight line. Since such a light is extremely close compared to the moon, maintaining a similar angle to the light source causes a useless or deadly spiral fly path for moth and the moth eventually converges toward the light. The mathematical model this behaviour can be proposed as an optimizer called Moth-Flame Optimization (MFO) algorithm.

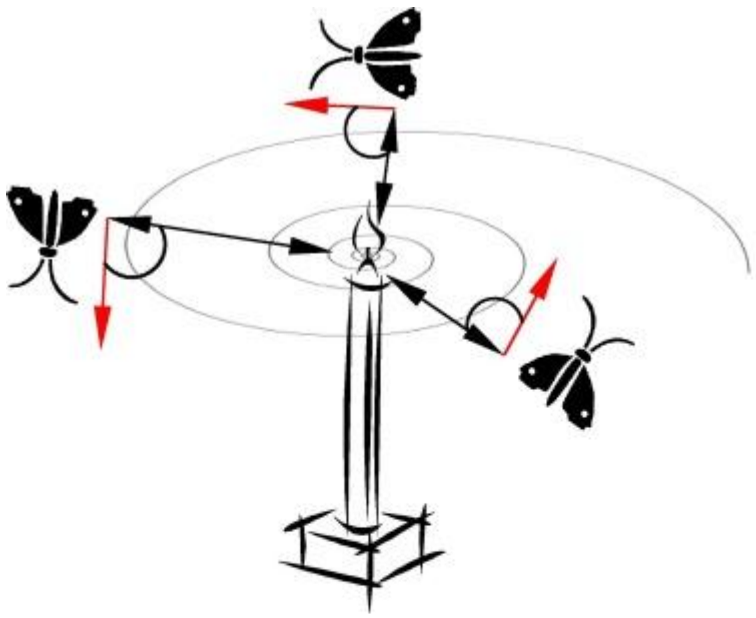

Fig. 5: Spiral movement of moth towards flame.

In this algorithm, the flame is taken as the best solution while the position of moth with reference to flame is taken as the solution at a given time. The population of moths represents all possible solutions from which one best optimal solution is found. Moth Flame Optimization is reported to be the best algorithm for searching the search space (exploration) due to individual searching of moth around the flame which in turn avoids local stagnation. The first step is to generate a set of random initial solutions**.** Each of these solutions is considered as a candidate solution for a given problem, assessed by the objective function, and assigned an objective value. The algorithm then combines/moves/updates the candidate solutions based on their fitness values with the hope to improve them. The created solutions are again assessed by the objective function and assigned their relevant fitness values. This process is iterated until the satisfaction of an end condition. At the end of this process, the best solution obtained is reported as the best approximation for the global optimum. A logarithmic spiral as the main update mechanism of moths subject to the following conditions:

- Spiral's initial point should start from the moth
- Spiral's final point should be the position of the flame
- Fluctuation of the range of spiral should not exceed from the search space

Moth-flame optimization analogy to Load dispatch

Decision variable(dimensions)	Number of generators in a system
Moths' position	Dispatched power
Fitness	Generation cost considering Emissions
Lower and upper boundaries	Generator Limits

3.0 RESULTS AND DISCUSSIONS

3.1The tests are conducted on standard IEEE-30 bus system.

Table 2: The Thermal cost coefficients and Emission coefficients.

Thermal Unit	Fuel cost co-efficients			P G min	P G max	□i (Kg/MW2hr)	□i (Kg/MWhr)	□ i (Kg/hr)
	a	b	C	MW	MW			
G1	0.15247	38.539	756.79	10	125	0.00419	0.3267	13.85932
G2	0.10587	46.159	451.32	10	150	0.00419	0.3267	13.85932
G3	0.02803	40.396	1049.99	35	225	0.00683	-0.54551	40.2669
G4	0.03546	38.305	1243.53	35	210	0.00683	-0.54551	40.2669
G5	0.02111	36.327	1658.56	130	325	0.00461	-0.51116	42.89553
G6	0.01799	38.27	1356.65	125	315	0.00461	-0.51116	49.89553

Table 3: Value of cost Penalty factor for emissions at various loads

Load	hi
1000	47.82
1200	62.04
1400	66.25

Table 4: Power output for PV units.

Unit/ Power	Min.	Max.	Avg.
PV1	30.38	38.31	31.36
PV2	48.67	67.37	51.45
PV3	94.27	115.89	100.7
PV4	120.24	142.94	139.15

3.2 Results obtained by using GRG Algorithm of Solver

Table 5: Cost of Load Dispatch

	Cost of Load Dispatch of 6 Thermal Units and 4 Thermal Units interconnected to 4 PV units											
	1000MW				1200MW				1400MW			
Unit	without PV		With PV		without PV		With PV		without PV		With PV	
	Scheduled Load	cost	Load	cost	Load	cost	Load	cost	Load	cost	Load	cost
Th.G1	102.9	10726.8	51.2	5119.3	125	15411.6	104	12242	125	15916.28	115.08	14295
Th.G2	106.1	11115.8	46.6	4656.5	148.4	19225.7	150	19506	150	20166.15	119.12	14887
Th.G3	158.5	14151.3	107	8580.5	186.4	20472.7	139	13167	225	28998.83	161.18	16886
Th.G4	158.1	14153.9	108	8697.3	185.7	20404.9	139	13178	210	25882.07	160.88	16888
Th.G5	237.7	20181.4	162	12003	277.4	29233.5	188	15984	325	39786.05	239.95	23890
Th.G6	236.7	20377.6	160	12093	277.1	29603.6	187	16329	315	38136.16	239.27	24229
PV 1			38.3	262.75			30.4	244.2			38.31	262.75
PV 2			67.4	441.65			48.7	397.89			67.37	441.65
PV 3			116	827.05			94.3	776.46			115.89	827.05
PV 4			143	1102.6			120	1049.5			142.94	1102.6
Total		**90707**		**53784**		**134352**		**92874**		**168886**		**113709**
%saving in cost		**40.70542893**				**30.87276185**				**32.67113363**		

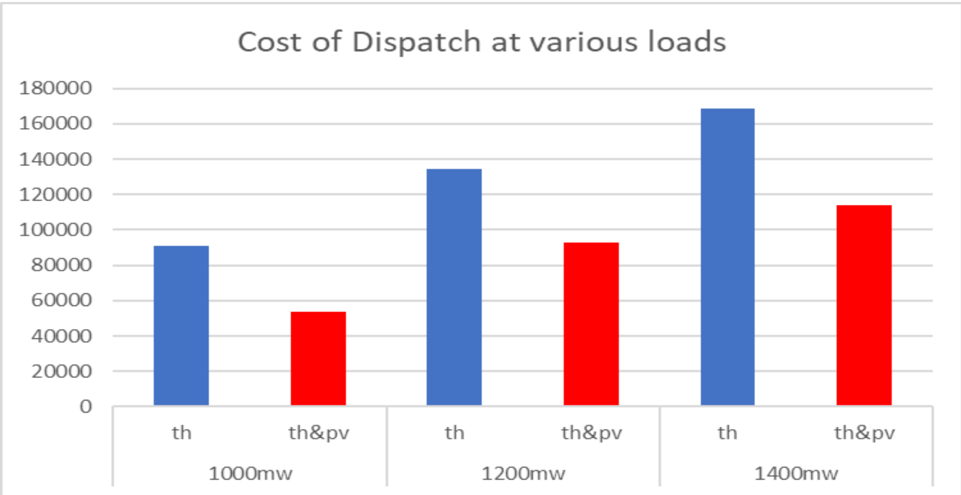

Fig. 5: Comparison of cost chart.

3.3 Results obtained by Moth Flame Optimizing Algorithm.

Cost of Load dispatch using MFA						
Unit/ Load	1000 MW load		1200MW load		1400MW	
	Scheduled Load	cost	Scheduled Load	cost	Scheduled Load	cost
PV1	50.21716	381.948	59.12339	471.2692	57.3903	422.995
PV2	52.79263	387.897	65.17802	485.255381	86.4171	676.1
PV3	52.49717	387.215	65.44738	485.877617	170.252	1325.86
PV4	159.9879	1223.55	204.6096	1547.38358	176.274	1339.77
Th1	32.34737	3059.17	34.58078	3721.49864	94.7093	6882.27
Th2	46.40018	3832.73	58.6483	5090.64934	130.92	8784.58
Th3	80.07767	5698.17	82.76038	6632.9216	131.243	8802.78
Th4	99.49282	7256.32	130.5131	8919.73065	145.019	9714.62
Th5	216.8567	12635.7	259.854	17219.6716	197.868	13125.4
Th6	209.3304	16731.2	239.285	19813.1038	209.908	17706.2
Total		**51594**		**91387.38**		**112781**

Algorithm/Load	1000MW	1200MW	1400MW
GRG	**53784**	**92874**	**113709**
MFA	**51594**	**91387.38**	**112781**
%difference	4	1.6	0.8

CONCLUSION

By interconnecting PV to the main grid near load ends, the cost of dispatch is greatly reduced**.** MFA gives better result than GRG, but it is easy to run and execute GRG in any system having MSOffice, but to run and execute MFA the knowledge of JAVA, MATLAB or Python etc is a must and also they have to be installed**.** Also when the number of parameters are considered, MFA works the best.

REFERENCES

1. S Prabhakar Karthikeyan, K Palanisamy, "Comparison of Intelligent Techniques to Solve Economic Load Dispatch Problem with Line Flow Constraints" @ IEEE International Advance Computing Conference, 2009.
2. K.Senthil,K.Manikandan,"Economic Thermalpower dispatch with emission constraint and valve point effect loading using improved Tabu search Algorithm", IJCA, july-2010; 3(9).
3. Barun Mandal,Provas Kumar Roy,Sanjoy Mandal,"Economic Load dispatch using Krill Herd Algorithm", Electrial Power and energy systems, 2014; 57: 1-10.
4. H. M. Dubey, B. K. Panigrahi, and M. Pandit, "Bio-inspired optimisation for economic load dispatch: a review," IJBIC, 2014; 6(1): 7–21.

5. Azza A. ElDesouky, “Security and Stochastic Economic Dispatch of Power System Including Wind and Solar Resources with Environmental Consideration” International Journal Of Renewable Energy Research, 2013; 3(4).
6. Dongara Ganesh Kumar Dr.P.Umapathi Reddy, ”Combined Emission Dispatch and Economic Dispatch of Power System Including Renewable Sources”, IJAREEIE, 2017; 6(5).
7. Chapter- 6 “Economic Load Dispatch of Power System Integrating Wind and Solar Energy”.
8. Binitha S, S Siva Sathya,”A Survey of Bio inspired Optimization Algorithms” IJSCE, May 2012; 2(2).
9. H. M. Dubey, B. K. Panigrahi, and M. Pandit, “Bio-inspired optimisation for economic load dispatch: a review,” IJBIC, 2014; 6(1): 7–21.
10. Velamuri Suresh, Sreejith S,”Economic Dispatch and Cost Analysis on a Power System Network Interconnected With Solar Farm”, International Journal Of Renewable Energy Research V. Suresh and S.Suresh, 2015; 5(4).
11. N. A. Rahmat#, N. F. A. Aziz#, M. H. Mansor#, I. Musirin*,”Optimizing Economic Load Dispatch with Renewable Energy Sources via Differential Evolution Immunized Ant Colony Optimization Technique “,
12. Nishant Saxenaa SouvikGangulib*,”Solar and Wind Power Estimation and Economic Load Dispatch Using Firefly Algorithm “, Procedia Computer Science, 2015; 70: 688 – 700. 1877-0509 © 2015 Published by Elsevier.
13. Er.Amit Bharadwaj, Prof.R.K.Sharmaa,Er.Ashuthish Bhadoria,” A case study of various constraints affecting Unit commitment in Power system planning”, IJERSTE, 2012; 1(2).
14. S.K.Guptha, Pankaj Chawala,’economic load dispatch in thermal power plant considering additional constraints using curve fitting and Ann”, Review of Energy technology and Policy research, 2015; 2(1): 16-28.
15. Peter Ozaveshe Oviroh and Tien-Chien Jen,” The Energy Cost Analysis of Hybrid Systems and Diesel Generators in Powering Selected Base Transceiver Station Locations in Nigeria”,an Article in Energies, 2018.
16. Narendra Kumar Yegireddy, Sidhartha Panda, Umesh kumar Rout and Rama Kishore Bonthu,“Selection of Control Parameters of Differential Evolution Algorithm for Economic Load Dispatch Problem”, Computational Intelligence in Data Mining - Volume 3,Smart Innovation, Systems and Technologies, 33.

17. Alaa F. Sheta," Solving the Economic Load Dispatch Problem Using Differential Evolution".
18. S. K. Dewangan, A. Jain, and A. P. Huddar, "Comparison of particle swarm optimization with lambda iteration method to solve the economic load dispatch problem," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, April 2010; 4: 1900–1907.
19. "Comparative analysis of optimal load dispatch through evolutionary algorithms," Ain Shams Engineering Journal, 2015; 6(1): 107–120.
20. Vinay K. Jadouna, Nikhil Guptaa, K. R. Niazia, Anil Swarnkara, R.C. Bansalb,"Multi-area Economic Dispatch using Improved Particle Swarm Optimization "Energy Procedia, 2015; 75: 1087 – 1092.
21. Muhammad Wajahat Hassan 1, Muhammad Babar Rasheed 1,*, Nadeem Javaid 2 Waseem Nazar 1 and Muhammad Akmal,' Co-Optimization of Energy and Reserve Capacity considering Renewable Energy Unit with Uncertainty ".an article in Energies, MDPI, 2018.
22. Ghulam Abbas1, Jason Gu2,3, (Senior Member, Ieee),Umar Farooq2,4, (Graduate Student Member, Ieee),Muhammad Usman Asad1, (Student Member, IEEE),and Mohamed El-Awary2, (Fellow, IEEE),"Solution of an Economic Dispatch Problem through Particle Swarm Optimization:A Detailed Survey – Part I, IEEE acess, August 2017.
23. Vishal Verma, Shivani Sehgal Mehta, Radhika,' Hybrid WOA-BAT algorithm for solving optimum load dispatching problem in power system with solar integration", Studies in Indian pace names, Jan 2020; 40(1).
24. Gaurav Dhiman,"MOSHEPO: a hybrid multi-objective approach to solve economic load dispatch and micro grid problems", © Springer Science+Business Media, LLC, part of Springer Nature, 2019.
25. Rui Pinto, Leonel M.Carvalho et.al, "Coping with Wind Power Uncertainity in Unit Commitment: a Robust Approach using the New Hybrid Metaheuristic DEEPSO", Jan 2020.
26. Yamina Ahlem Gherbi, Hamid Bouzeboudja, Fatiha Lakdja, "Hybrid metaheuristic for the combined economic dispatch problem".
27. Julia Sachs, Marcus Sonntag, Oliver Sawodny, "Two Layer Model Predictive Control for a Cost Efficient Operation of Island Energy Systems, @ American Control Conference, Palmar House Hilton July 1-3, 2015 Chicago, IL, USA, 2015.

28. Saida Makhloufi, Abdelouahab Mekhaldi et.al, "Hybridization of Modified Particle Swarm Optimization with Gravitational Search Algorithm for Solving Optimal Power Flow Including Wind Generation in Isolated Adrar Region".
29. Bratati Ghosh, Bishwajit Dey, Aniruddha Bhattacharya, "Solving Economic Load Dispatch using Hybrid Krill Herd Algorithm".
30. O H Abdel Satar, Saad M A Eid et.al, "Adaptive and Reliable Control Algorithm for Hybrid System Architecture" @ International Journal of Computer Science, January 2012; 9(1).
31. Ali Vaseghi Ardekani, Hamid Reza Forutan et.al,"An Intelligent Approach for Management of Hybrid DG System" @ World Academy of Science, Engineering and Technology International Journal of Electrical, Robotics, Electronics and Communication Engineering, 2014.
32. Dr. T Govindaraj, M Vidhya, "Optimal Economic Dispatch for Power Generation Using Generic Algorithm" @ International Journal of Innovative research in Electrical, Electronics, Instrumentation and Control Engineering, 2014.
33. Xingyu Li, Dongmei Zhao, "An Optimal Dynamic Generation Scheduling for a Wind-Thermal Power System" @ Energy and Power Engineering, 2013.
34. Congcong Wang, Nivad Navid, "Ramp Requirement Design for Reliable and Efficient Integration of Renewable Energy", @ National Science Foundation.
35. Saoussen BRINI, Hsan Hadj Abdallah, Abderrazak Ouali, " Economic Displtch for Power System included Wind and Solar Thermal energy" @ academicdirect.org.
36. H T Jadhav, Harsh Bhandari et.al, "Economic Load Dispatch Including Wind Power Using Plant Growth Simulation Algorithm".
37. Longzhu Xiong, Rui Ma, "A New Model and Algorithm in Power System Economic Dispatching with Fluctuating Load and Wind Power" @ Hunan Electric Power Company of the State Grid Grant.
38. Emrah Biyik, Ramu Chandra, "Optimal Control of Microgrids – Algorithms and Field Implementation", @ American Control Conference, 2014.
39. Maria Luisa Di Silvestre, Giorgio CRanditi, Eleonora Riva Sanseverino, " A Generalized Framework for Optimal Sizing of Distributed Energy Resources in Micro-Grids Using an Indicator-Based Swarm Approach, @ IEEE Transactions on Industrial Informatics, 2014.
40. S Prabhakar Karthikeyan, K Palanisamy, "Comparison of Intelligent Techniques to Solve Economic Load Dispatch Problem with Line Flow Constraints" @ IEEE International Advance Computing Conference, 2009.

41. WILBERT RUTA, Pan African University Institute For Basic Sciences, Technology And Innovation, A thesis on "Economic dispatch considering emissions using moth flame optimization and bat hybrid algorithm", 2018.
42. NREL, https://pvwatts.nrel.gov/pvwatts.php.
43. S. Mirjalili, Moth-Flame Optimization Algorithm: A Novel Nature-inspired Heuristic Paradigm, Knowledge-Based Systems doi: http://dx.doi.org/10.1016 /j.knosys.2015.07.006, 2015.
44. Svetlana Cheusheva | updated on October 9, 2020 https://www.ablebits.com/office-addins-blog/2016/06/22/how-to-use-solver-in-excel-with-examples.