is also shifted to Carbon Credits and Kyoto Protocols [3]. To meet the above re uirements, low emission fuels and post combustion cleaning systems are re uired. Fuel switching to low emission level are costly. Further time and maintenance are involved in post combustion cleaning system. In view of this there is a sheer need to minimum emission discharge power generation schedules in day to day operation of power systems.Due to the above reasons in contrary to Economic fuel dispatch, some of the researchers proposed Minimum Emission dispatch [2]. But both Economics and Environment electrical power dispatch are conflicting and non-commensurable objectives [4,]. Final decision has to be made in a compromised way by Decision Ma er (DM) by using mathematical programming or recent soft computing techni ues [4].

Mathematical programming methods [5] are good at dealing with convex optimization problems. However, these methods need modification and require elaborate procedures when applied to hard non-linear, non-convex optimization problems of static and dynamic power system optimization problems. Last decade many heuristic optimization methods [6] developed by scientific community from the concept survival of the fittest (Genetic Algorithms(GA)[7]), natural behavior of bird or fish flocking (Particle Swarm optimization (PSO))[4],Big-Bang &Big-crunch[8] are applied to solve non-convex optimization . FireFly Optimization (FFO), a heuristic optimization that simulates Flashing behavior of fireflies (lighting bugs), developed by Dr Xin-She Yang[9] has been applied to solve many bench mark test functions.

This paper applies FFO to obtain Economic and Environmental dispatch independently to ascertain conflicting nature of both objectives. Further, the imprecision in Decision Making (DM) is resolved by forming a min-max optimization problem to arrive at final real power generation schedules that provides satisfactory improvement in real power losses and voltage profiles. The simulation results of application of FFO is also compared with Genetic approach [10] to arrive at conclusions about the final results of FFO. Population based methods have draw back of not converging to the exactly same solution all the time due to their stochastic nature. In this paper to access the uncertainty in final solutions, statistical measures such as standard Deviation and average objective function values are considered and compared with GA for the standard power system transmission network.

2.0 Problem formulation:

2.1 Economy:

In general, fuel cost of power generating units is approximated as quadratic cost function of real power outputs. Thus, the total cost of all units involved in real power generation is as follows.

$$F_1(pg) = \sum_{i=1}^{Ng} (a_i + b_i P_{gi} + c_i P_{gi}^2) \tag{1}$$

where a_i, b_i, and c_i are cost coefficients .When each steam admission valve in turbine starts to open gradually, a rippling effect on the unit curve is produced, this effect can be modeled as rectified sinusoidal contribution to the quadratic cost functions[3]. Therefore, with valve point loading effects total cost of real power generation is as given below.

$$f_1(Pg)=\sum_{i=1}^{Ng}\left[a_i + b_i P_{gi} + c_i P_{gi}^{\ 2} + \left| d_i \times \sin\left\{ e_i \times \left(P_{gi}^{\min} - P_{gi} \right) \right\} \right| \right] \qquad (2)$$

where d_i, e_i are valve point coefficients , P_{gi}^{min} and P_{gi}^{max} are lower and upper power generation limits of thermal generating units respectively .

2.2**Emission**:

Thermal power stations are a major cause of atmospheric pollution because of high concentration of pollutants that they produce post combustion.The Emission curves can be directly related to the cost curve through the factor emission rate per megajoules (1 Btu=1055.06 J),which is a constant factor for a given type or grade of fuel, thus yielding quadratic NO_X ,SO_2,and CO_2 Emission curves in terms of real power generations similar to equation(1). Emission can be more accurately [3]expressed as sum of quadratic and exponential function as indicated below with emission co-efficients.

$$f_2(Pg) = \sum_{i=1}^{N_g}\left[a_i + \beta_i P_{gi} + \gamma_i P_{gi}^2 + \eta \exp\left(\delta_i P_{gi}\right)\right] - \qquad (3)$$

2.3 Mini-max scalar optimization:

The two objectives Economy (f_1) and Emission (f_2) are conflictive in nature a trade off solution (compromised solution) can be a candidate solution to over come imprecision by DM. To obtain such compromised solution minimization of equation (4), is called as Min-Max optimization. The solution provided by Min-Max optimization may be considered as final decision by the Decision Maker (DM) in resolving the multiple choices available for decision making.

$$f_3 = \max\{d\} - \qquad (4)$$

where f_3 is minimization of the maximum deviations of $f_1$and f_2.The„d" is defined as follows

$$d = \left[\frac{|f_m - f_m^{min}|}{f_m^{min}}\right] - \qquad (5)$$

where m=Number of objective functions .

2.4 Optimal Power Flow (OPF) constraints:

In general minimization of equation (1) or (2) or (4) can be formulated as OPF subjected to the following power transmission System constraints. They are

a) Real power balance equality constraints.

P_i (V,δ) -$P_{gi} + P_{di}$ = 0. (i=1, 2, 3,………NB)

Reactive power balance in the network

$Q_i(V,\delta)$ -$Q_{gi} + Q_{di}$ = 0. (i=1,2,………NL)

Where V,δ are magnitude of bus voltages ,bus angles. NB,NL are number of buses and load buses respectively.

b) In general a large scale optimal dispatch considers a number of functional constraints. In this paper Limitation on real power and reactive power resources and operational constraints of load bus bar voltages are considered as inequality functional constraints.

(i) Generator real(P_{Gi}) and Reactive power (Q_{gi})limits:

$$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max}$$
$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}$$

Where $i \in NG$ (Number of generating units)

(ii) Load Bus Voltages:

$$V_i^{min} \leq V_i \leq V_i^{max} \quad i \in NL$$

Thus the objective or goal of the paper is to obtain real power control variables (Pg) of a power system network that provides a compromised solution to the two conflicting objectives of this paper by solving individually $f_1$and $f_2$to obtain Economic dispatch and Environmental dispatch. and then using min-max equation (4) to arrive at a compromised solution.Note that in equation (4) instead of f_m^{min} any desired value of m[th] objective function value as desired by DM can be used to obtain non-inferior solutions. In general for a candidate solution (P) ,the equality constraints are satisfied by Newton Raphson power flow method. Load bus bar voltages and load flow dependent slack bus real power generation are brought within the limits by penalty method approach. With inclusion of penalties the objective function takes the following form.

$$\min\ FF = F_m(P_g) + P_S + P_{vi} \tag{5}$$

where $P_s, P_{vi},$ and are as follows

$$P_s = P_{ens}\left(P_{gs} - P_{gs}^{lmt}\right)^2,\ where \qquad P_{gs}^{lmt} = \begin{cases} P_{gs}^{min}; if\ P_{gs} < P_{gs}^{min} \\ P_{gs}^{max}; if\ P_{gs} > P_{gs}^{max} \end{cases}$$

$$P_{vi} = P_{env}\sum_{i=1}^{NPQ}\left(V_i - V_i^{lmt}\right)^2, where\ V_i^{lmt} = \begin{cases} V_i^{min}; if\ V_i < V_i^{min} \\ V_i^{max}; if\ V_i > V_i^{max} \end{cases}$$

here P_{ens} , P_{env} penalty values for the slack bus generator MW limit violation, Load bus voltage limit violations respectively.

3.1 FIREFLY OPTIMIZATION (FFO)

Fireflies, randomly distributed in space, emit light due to photogenic organs on their surface for various social behavior such as prey attraction, warning signals to a predator. The position of each firefly can be located using co-ordinate points. The brighter firefly emits more light to attract other fireflies. The other fireflies, which are lesser in brightness, get attracted towards brighter one, by updating their positions. Thus, fireflies keep moving in space till all of them reach same position (towards brighter one). This social behavior of fireflies is mathematically simulated by introducing an attraction factor that depends on the position of Firefly. The brightness of firefly is proportional to the maximum of function to be optimized. The co-ordinates of each firefly are analogous to control variables of the optimization function to be optimized. The attraction towards brighter one is simulated as monotonically decreasing function.

$\beta(r) = \beta_o \exp(-\gamma r^2)$ (6)

In the above equation r is the distance between any two fireflies, β_o is the initial attractiveness and γ is an absorption co-efficient which controls the light intensity between two fireflies. The movement of firefly j, with row vector $u^{(j)}$ as co-ordinates can be moved to a more brighter firefly i , with row vector $u^{(i)}$ *as* co-ordinates by using the following update equation for firefly j ,

$u^{(j)} = u^{(j)} + \beta_o \exp(-\gamma r^2).(u^{(i)} - u^{(j)}) + (\alpha$*rand (1, NC)-0.5) (7)

where "α" is step size, „rand" is uniform random number between 0 and 1.In equation 7, first term is
current position (co-ordinates) of firefly j, second term is the attractiveness factor and last term
allows random movement of firefly. FFO is maximization algorithm. In this paper, in each generation
of FFO, function values are sorted in descending order. Minimum of function value is considered as
the brightest firefly, all other fireflies are moved to the brighter one as per equation 7. The implementation of FFO optimization is presented in what follows.

3.2 Steps to implement FFO

Similar to most of the population based optimization methods FFO also initiates search with random feasible candidates within the limits of problem specific search variables. Each of population methods of optimization differ only in selection criteria of current best candidates and generation of successive better population till the termination criteria of the optimization. Generation of successive better population in FFO is due to equation(7).In what Follows the application of FFO to the problem considered in this paper is explained.

1. Read data (Economic & Emission coefficients of objective function, Line, bus data and location of Generators) in power system network.
2. Generate initial control variable matrix P_g of size (NP*NC) within the lower and upper
limit of control variables i.e i^{th} row of P_g can be generated as

$$p_g^i = P_g^{MIN} + (P_g^{Max} - P_g^{Min})*\text{rand}(1, NC).$$

where „rand" is uniform random number [0, 1], and P_g^{Max} and P_g^{Min} are Maximum and Minimum limits of control variables respectively . Typically P_g^{Max} and P_g^{Min} are row vectors of dimension (1*NC) .

In this step in-equality constraints on real power generating units are implicitly generated.

3 Set Major iteration count k=1.
4. Initialize population counter j= 1. Set Row select P_g to 1.
5. Fetch the row corresponding to Row select from P_g, modify bus data of power system network. Solve for power balance equation and obtain power system state variable (V,δ) by using Newton Raphson (NR).

6. Evaluate objective function value FF(j) .
set Row select=Row select +1,j=j+1, return to 5, till j=NP.

7. Sort function values in descending order and Store current best solution and its corresponding control variables(P_g) .check for stopping criteria, if met display current best solution, else go to step next step.
8. Update control variables in accordance with update Equation 7.This step may result in violation of control variable limits. Those violated control variables should be made equal to their respective violated limit.
9. Set k=k+1.Return to step 3 till k=Maximum iteration count.
Convergence criteria may be number of generations or difference between best function value of k^{th} and $(k+1)^{th}$ generation less than a specified tolerance. The above steps are implemented for the test system mentioned in this paper. The required code is written in MATLAB-7.0, as m-files using library routines of MATLAB soft ware. Code is executed on a 2.1 GHz, Pentium IV PC.
Parameters of FF0 are γ and β_o are set to unity with Population size NP=40. Step size α can be chosen between [0 1]. Inorder to over come the premature termination of optimization α at local optimum point[ ] and to adequately explore the objective function landscape α is considered as (α=0.974* α),with α as unity at the start of major iteration count K of the optimization.

4.0 Discussion of results :
Test System considered for simulation is Gangour -25 [2] bus system with 35 transmission lines,5 generators . Fuel Cost and Emission coefficients are taken from [11] . Total base case load of the system (7.3pu+j2.23pu) on 100MVA base.
Parameters of FF0 are γ and β_o are set to unity with Population size NP=40. Step size α can be chosen between [0 1]. In order to over come the premature termination of optimization α at local optimum point and to adequately explore the objective function landscape α is considered as α=0.974* α,with α as unity at the start of major iteration count K of the optimization.
The f_1^{min} and f_2^{min} are found to be 2151.0493$ and 1112.6852 lb respectively. While optimizing f_1 alone the unacceptable high Emission level f_2 is found to be 1242.8064 lb. when preference is given to minimization of f_2 the unacceptable high cost of fuel f_1 is found to be 2458.8268 $.To resolve this conflict Minimization of function f_3 is carried out to obtain a compromised solution. The compromised solution for f_1 and f_2 is found to be 2295.6730 $and 1187.4941 lb respectively. In order to have an idea about voltage profiles of load bus voltages ,a sum squared voltage deviation from flat voltage of bus bars ,voltage stability index[12] V_{se} is computed. Generation schedules along with V_{se} and real power losses in pu are provided in Table 1.

Table 1:- Generation schedules ,real losses and voltage stability index.

Function	P_{g1}	P_{g2}	P_{g3}	P_{g4}	P_{g5}	LOSS	V_{se}
f_1	2.2956	0.9861	1.3234	0.75	2.0982	0.1534	0.0016
f_2	1.7068	1.2031	1.75	0.75	2.1032	0.2131	0.0019
f_3	2.1528	0.9850	1.4791	0.7475	2.0982	0.1625	0.0017

It is clear from the above narration and Table 1 that the proposed algorithm of this paper has provided reduced cost solution compared to minimization of f_2 and at the same time Emission level is also reduced compared with f_1 minimization with better real losses and voltage profiles to near unity. The proposed FFO of this paper is also compared with Genetic Algorithm.In order to access the performance of FFO and GA ,both optimization methods are repeated 10 times with different initial random Pick of control variables .The statistical measures such as mean and standard deviations(Std) are computed to access both optimizations in optimizing all the three functions considered in this paper. Table 2 indicates Comparison of trade –off results of FFO with GA .

Table 2:- Trade off results comparison with GA

Function	FFO		GA	
	Cost	Emission	Cost	Emission
f_1	2151.0	1242.8	2155.1	1246.6
f_2	2458.8	1112.7	2470.0	1113.1
f_3	2295.7	1187.5	2307.8	1193.5

From Table 2, it is very clear that for all three functions FFO provided better trade of solution.

Statistical results indicated in Table 3 further confirm the reliability of the proposed algorithm.

Table 3:- statistical comparison with GA

Function	FFO		GA	
	mean	Std	mean	Std
f_1	2173.8	25.5	2191.8	58.2
f_2	1112.7	0.03	1114.3	1.15
f_3	0.077	0.0044	0.079	0.0053

This is to be observed form Table 3 that the standard deviation for both optimizations are high for minimization of f_1 alone .FFO has better reliability for economic optimization for the nature of the cost curves considered in this paper. Also it is to be observed from Table 3 for optimization f_2 and f_3 from the point of reliability of algorithm both optimizations are reliable with a clear better edge to FFO.

5.0 Conclusion: In this paper recent fire fly optimization is applied to solve economic and environmental Dispatch problem and has proposed min-max optimization to resolve the imprecision in Decision Making. Digital Simulation results in solving cost functions of non-convex nature and comparison with popular GA based approach confirmed the better capabilities of FFO.

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