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Firefly Algorithm for Optimal Power Flow Considering Control Variables

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Abstract*:* Optimal Reactive power Dispatch is an important case of optimal power flow (OPF) problems. These optimal power flows problems are solved by using many swarm based algorithms are used. This swarm based algorithms some achieve better global optimal solutions, and many do not achieve the global optimal solution. When this paper study about newly introduce Firefly algorithm and this algorithm how to implement to solve optimal power flow problems and how to achieve better global optimal solutions are briefly discussed in this paper**.**

Keywords*:* Optimal Reactive power dispatch, optimal power flow, swarm based algorithm, Firefly algorithm**.**

I. INTRODUCTION

Day to day life increase the demand of Electricity when the continuous growth of the population so nowadays the generations are not equal to the demand. So, insufficient power generations are occurring the transmission capacity expansion, voltage instability, insufficient reactive power sources are the main problem for voltage collapse. This is the main problem of power systems. When the power system contains large problems these problems are used to solve optimal power flow techniques.

This optimal power flow problems are overcome by reallocate of reactive power generation. when this achieved by adjust the generator bus voltage, transformer tap setting, VAR output from the shunt compensating devices These are the control variables in Optimal reactive power dispatch(ORPD). In addition the real power loss also optimized the help of reallocate of reactive power generation[2,3].Some swarm based optimization methods are solve optimal power flow problems and also try to achieved global optimal solutions. Many algorithms do not achieve globally optimal solutions. When this newly introduce Firefly algorithm and this algorithm how to implement to solve optimal power flow problems and how to achieve better global optimal solutions are briefly studied in this paper.[4, 15],[16]-[29].

II. OPTIMAL POWER FLOW

The optimal power flow of OPF has had a long history in its development. It was first discussed by Carpenter in 1962 and took a long time to become a successful algorithm that could be applied in everyday use. Current interest in the OPF centres around its ability to solve for the optimal solution that takes account of the security of the system. We can solve the OPF for the minimum generation cost and require that the optimization calculation also balance the entire power flow at the same time. Note also that the objective function can take different forms other than minimizing the generation cost. It is common to express the OPF as a minimization of the electrical losses in the transmission system, or to express it as the minimum shift of generation and other controls from an optimum operating point.

The Optimal Power Flow has many applications including:

A. The calculation of the optimum generation pattern, as well as all control variables, to achieve the minimum cost of generation together with meeting the transmission system limitations. And using either the current state of the power system or a short-term load forecast, the OPF can be set up to provide a “preventative dispatch” if security constraints are incorporated.

B. In an emergency, that is when some component of the system is overloaded or a bus is experiencing a voltage violation, the OPF can provide a “corrective dispatch” which tells the operators of the system what adjustments to make to relieve the overload or voltage violation.

C. The OPF is routinely used in planning studies to determine the maximum stress that a planned transmission system can withstand. For example, the OPF can calculate the maximum power that can safely be transferred from one area of the network to another.

III. OPTIMAL REACTIVE POWER DISPATCH

The Main objective function here is to reduce the Real power loss (P_{LOSS}) in the transmission system. There are two basic approaches to loss minimization, namely the slack bus method and the summation of losses on individual lines .Sometimes it is desirable to Reduce losses in a specific area and hence, the second method which is more generic, is used in this work.

IV. EXISTING SYSTEMS

Existing system methods lists are given 1) Hybrid Particle Swarm Optimization (HPSO) 2) Biogeography Based Optimization (BBO) 3) Real Coded Mixed Integer Genetic Algorithm (MIGA) 4) Differential Evolution (DE) 5) Multi objective Evolutionary Algorithm.(EA).

A. Hybrid Particle Swarm Optimization

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This paper based on food searching behaviour of birds and the HPSO algorithm achieved to reduce the real power loss. When the loss is achieved by two methods, one is tangent vector techniques the difficult area of the power system is identified. Another one is determine the area, the HPSO techniques takes space to minimize the amount of shunt reactive power compensation in each bus. Such as real power loss is achieved by using control parameters are Generator Voltage magnitude, tap setting, and VAR sources.

B. Biogeography-Based Optimization

Biogeography is the study of nature's way of distributing Biological Organism. This concept based on Migration and Mutation. And it is achieved by two variables one is Habitat Suitability Index (HSI) these factors involve Rainfall, Diversity of vegetation, temperature, diversity of topographic features and land area. This HSI consist of Dependent variable.

This algorithm used to solve multi constrained optimal reactive power flow problem in power system. Multi constrained means to reduce the peal power loss and voltage deviation and to optimize simultaneously both. These optimization achieved by using some control parameters that are transformer tap setting, VAR injection of shunt compensators and generator voltages. These parameters are reallocate to reduce the real power loss and voltage deviation.

C. Real Coded Mixed Integer Genetic Algorithm

Genetic algorithm is one of the techniques to solve optimal power flow problems. It is proven to solve the non-convex optimal power flow (OPF) problems. It is deal with the continuous/discontinuous variables. The continuous variable consist of generator bus voltage magnitude and VAR injection values of static VAR Compensators. Discrete Variables consist of transformer tap settings and phase shifter angle positions, this algorithm used to achieve a better global optimal solution.

D. Differential Evolution:

This differential Evolution technique used to solve optimal power flow problems and to solve non-linear optimal power flow problems also minimizes the real power loss. This minimization achieved by adjusting the control parameters that are generator terminal voltage, tap position these are the parameter to reduce the real power loss.

E. Multi objective Evolutionary Algorithm:

This algorithm contain Optimal reactive power dispatch problem is presented. This technique used to reduce real power loss and voltage deviations are to be optimized simultaneously.

This Multi objective Evolutionary Algorithm used to solve a new strength Pareto Evolutionary based method used. When the loss minimization achieved by adjust the some control parameters that are Transformer taps, generator voltage, switchable VAR sources.

V. PROBLEM FORMULATION

A. Objective function

The objective function of this work is to find the optimal settings of reactive power control variables including the rating shunt of var compensating devices which minimizes the real power loss and voltage deviation. Hence, the objective function can be expressed as:

$$f = min(P_L) \quad (1)$$

The total real power of the system can be calculated as follows p

$$P_L = \sum_{k=1}^{N_L} G_k [V_i^2 + V_j^2 - V_i V_j \cos(\delta_i \delta_j)] \quad (2)$$

Where , N_L is the total number of lines in the system; G_k is the conductance of the line '*k*'; V_i and V_j are the magnitudes of the sending end and receiving end voltages of the line; δ_i and δ_j are angles of the end voltages.

B. Constraints

The minimization problem is subject to the following equality and inequality constraints

B.1. Equality constraints**:**

Load Flow Constraints:

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} \cos\left(\delta_{ij} + \gamma_j - \gamma_i\right) = 0 \quad (3)$$

$$Q_{Gi} - Q_{Di} - \sum_{j=1}^{N_B} V_i V_{ij} Y_{ij} \sin\left(\delta_{ij} + \gamma_j - \gamma_i\right) = 0 \quad (4)$$

B.2. Inequality constraints:

Reactive Power Generation Limit of SVCs:

$$Q_{ci}^{min} \leq Q_{ci} \leq Q_{ci}^{max}; i \in N_{SVC} \quad (5)$$

Voltage Constraints:

$$V_i^{min} \leq V_i \leq V_i^{max}; i \in Nb \quad (6)$$

Flow limit:

$$S_i \leq S_i^{max}; i \in N_l \quad (7)$$

Tap position Constraints:

$$T_{pi}^{min} \leq T_{pi} \leq T_{pi}^{max}; i \in N_T \quad (8)$$

VI. PROPOSED SYSTEMS

A. Firefly Algorithm

This paper used to solve non-linear design problems. This technique used to reduce real power loss and improve the voltage profile and these are achieved by with help of to adjust the control parameters such as transformer tap settings and VAR outputs from shunt compensating devices are the control parameters. And this algorithm used how to determine better global optimal solutions are given below. To find global optimal solutions is achieved by help of two test functions one is singularity (or) stochastic another one is deterministic.

Stochastic method produce different solution evens the same starting point. Deterministic method produce the same set of solution of even with the same starting point. These Deterministic algorithms are to find efficient local

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optima. It is difficult to find the global optimal solution. So, stochastic method used to find global optimal solution. Most stochastic algorithms can be considered as meta-heuristic, and good examples are genetic algorithms (GA) and particle swarm optimisation (PSO). Many modern meta-heuristic algorithms were developed based on the swarm intelligence in nature. Stochastic method has a deterministic component and a random component. Stochastic method can take many forms such as simple randomization by randomly sampling the search space or by random walks.

B. Fireflies Algorithm

The fireflies characteristics are the following three rules are given below.

1) All fireflies are unisex so that one firefly is attracted to remaining fireflies regardless of their sex.

2) Attractiveness is proportional to their brightness thus for any two flashing fireflies the low brighter one will move towards the higher brighter one. The attractiveness is directly proportional to the brightness and they both decrease as their distance increases. If no one is brighter than a specified firefly, it moves randomly.

3) The brightness or light intensity of a firefly is determined by the landscape of the objective function to be optimised.

C. Attractiveness and Light Intensity

In the Firefly algorithm, there are two important issues: the variation of the light intensity and the formulation of the attractiveness. We know, the light intensity varies according to the inverse square law i.e.:

$$I(r) = \frac{I_s}{r^2} \tag{9}$$

Where $I_{(r)}$ is the light intensity at a distance r and I_{sis} the intensity at the source. When the medium is given the light intensity can be determined as follows:

$$I(r) = I_0 e^{-\gamma r} \tag{10}$$

To avoid the singularity at r=0 in the equations can be approximated in the following Gaussian form.

$$I(r) = I_0 e^{-\gamma r^2} \tag{11}$$

As we know, that a firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies and thus the attractiveness β of a firefly is determined by β_0 and the β_0 attractiveness at r=0

$$\beta = \beta_0 e^{-\gamma r^m} (m \geq 1) \tag{12}$$

D. Distance:

The distance between any two fireflies i and j at xi and xj respectively, the Cartesian distance is determined by equation where $X_{i,k}$ is the k^{th} component of the spatial coordinate xi of the i^{th} firefly and d is the number of dimensions.

$$r_{ij} = \sqrt{\sum_{k=1}^{d} \left(x_{i,k} - x_{j,k}\right)^2} \tag{13}$$

E. Movement

The movement of a firefly i is attracted to another more attractive (brighter) firefly j is determined by

$$x_i = x_i + \beta_0 e^{-\gamma r_{ij}^2}\left(x_j - x_i\right) + \alpha\epsilon \tag{14}$$

Where the second term is due to the attraction while the third term is randomization with α being the randomization parameter and ϵ being the vector of random numbers drawn from a Gaussian distribution. It is worth pointing out that is a random walk partial towards the brighter fireflies and becomes a simple random walk if $\beta_0 = 0$. The parameter set used in this work is described later.

*F.*ALGORITHM

Step 1: Start the program
Step 2: Enter the load system input data
Step 3: The Generate initial population of fireflies x_i (i = 1, 2, ..., n)
Step 4: To determine Light intensity I_i at x_i is determined By $f(x_i)$
Step 5: Set the iteration count iter=1
Step 6: To calculate i^{th} firefly for i = 1: n all n fireflies
Step 7: To calculate j^{th} firefly for j = 1:n all n fireflies
Step 8: To check if (Ij> Ii), Move firefly i towards j in d-dimension; end if
Step 9: To calculate attractiveness, whenAttractiveness varies with distance r.
Step10: To Evaluate new solutions and update light Intensity
Step11: end for j
Step12: end for i
Step13: Rank the fireflies and find the current best
Step14: To evaluate Iter=Iter+1
Step15: Check Iter > Itermax; the condition no means go to step 4.
Step16: Print the results
Step17: Stop the program.

The control variables are Generator bus voltage magnitudes, transformer tap settings and VAR outputs from shunt compensating devices are the control parameters in optimal power flow problems. These control parameter values are adjusted for loss reduction.

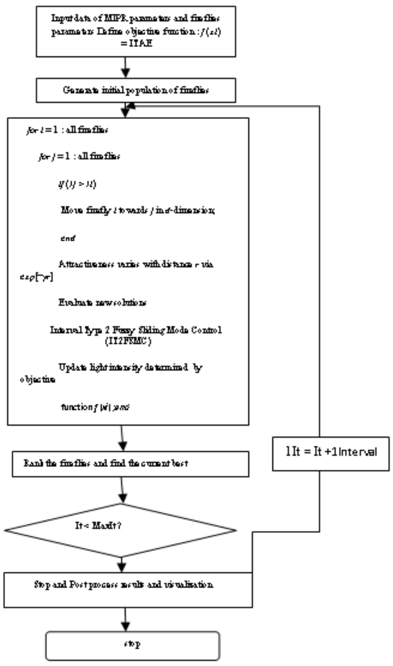

Fig.1. Flow Chart

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VII.SIMULATION RESULT AND DISCUSSION

The proposed FFA based method is tested on IEEE test systems. The algorithm is coded in Mat lab 7.6 programming language and a Core 2 Duo based PC is used for simulation.The systems are taken under base load conditions. The results obtained are discussed below. The control variables adjusted within their respective upper and lower bounds. The control variable ranges are shown in table 1.

TABLE I CONTROL VARIABLE LIMIT

Si. No	Control Variable	Limit
1	Generator voltage (V_{Gi})	(0.9-1.1) p.u.
2	Tap setting(T_{Pi})	(0.9-1.1) p.u.
3	MVAR by static Compensators (Q_{svc})	(0-5)MVAR

A. Minimization of Real Power Loss

The real power transmission loss minimization is the major component of reactive power optimization objective and it needs more attention. This case takes only the real power loss minimization as the objective function. The proposed algorithm is run and the optimal value of total line loss is obtained. Different objectives of loss minimization, voltage deviation minimization. Tuned values of control variables corresponding to different objectives are given in table 2

TABLE II OPTIMAL CONTROL VARIABLES

parameter	Optimal value by FFA	Optimal value by FOA
P_{g1}	172.3	175.50
P_{g2}	45.11	42.97
P_{g5}	10.20	19.07
P_{g8}	11.15	19.90
P_{g11}	20.22	12.82
P_{g13}	21.70	17.32
V_{g1}	1.058	1.10
V_{g3}	1.043	1.08
V_{g5}	1.098	1.05
V_{g8}	1.075	1.06
V_{g11}	1.020	1.03
V_{g13}	1.030	1.10
T_{p11}	1.065	0.95
T_{p12}	0.900	1.01
T_{p15}	1.040	1.07
T_{p36}	0.921	1.02
Q_{svc10}	19.0	8.03
Q_{svc24}	4.1	2.00

Real power optimization results by different algorithms are compared in table 2. It is clear that FFA is performing better than the DE and FOA algorithms. The reduction in reactive power by FFA is higher by 0.0264 than by DE. From table 2 it is clear that FFA outperforms other algorithms in loss minimization task.

TABLE III MINIMIZATION OF OBJECTIVE TERMS

Parameter	Real power loss minimization and voltage deviation		
	FFA	PSO	IGA
P_{loss}	12.46	12.55	13.30
V_D	0.303	0.400	0.405

VIII CONVERGENCE CURVE

For any large number of fireflies (NP), if n>>m, where m is the number of local optima of an optimization problem, the convergence of the algorithm can be achieved. Here, the initial location of NP fireflies is distributed uniformly in the entire search space, and as the iterations of the algorithm continue fireflies converge into all the local optimum. By comparing the best solutions among all these optima, the global optima are achieved. By adjusting parameters γ and α, the Firefly algorithm can outperform both the algorithms Harmony S Search

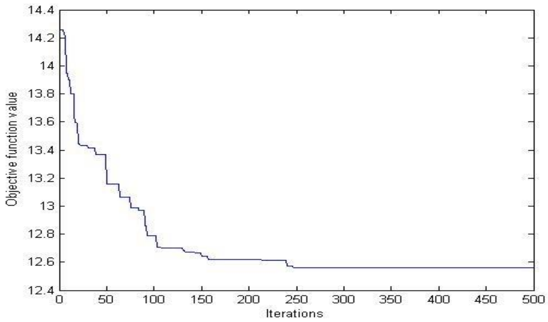

Fig 2: Convergence curve

algorithm and PSO. It can also find the global optima as well as the local optima simultaneously and effectively
Strength of an optimization technique is usually tested by its convergence reliability and speed. The excellent convergence quality of FOA is depicted in figure 2.

IX .CONCLUSION

In this paper A literature survey on Firefly algorithm is clearly explained eligible to solve optimal power flow non-linear problems. And these algorithm briefly explained about at attractiveness, distance, light intensity, movement is explained these parameters are helping to use Firefly algorithm eligible to solve multi constraint optimal power problems that means to minimize real power loss and voltage deviation are both achieved simultaneously. And it also achieves better global optimal solution.

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