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Optimal Power Flow Analysis using Two Stage Initialization based Flower Pollination Algorithm

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***Abstract*— In this paper, a new approach to solve optimal power flow (OPF) problem in power systems is presented. In the proposed algorithm, a two stage initialization process have been adopted and also it gives optimal solution with less number of generations which results in the reduction of the computation time. The feasibility of the proposed algorithm is demonstrated for IEEE 30-bus system with different objective functions. The OPF result of proposed algorithm is compared with existing algorithm. The results reveal better solution and computational efficiency of the proposed algorithm.**

Keywords— Two stage initialization, optimal power flow; optimization techniques; power system operation.

I. INTRODUCTION

In the optimal power flow problem, certain control variables are adjusted to minimize an objective function such as the cost of active power generation or emission or losses while satisfying operating limits on various control and dependent variables. The solution of OPF problem must satisfy the network security constraints. In the past, conventional methods like Newton's method [1-3] and Interior point method [4-6] were used to solve the OPF problem. But, in recent years, evolutionary methods are commonly used to solve the OPF problem than conventional methods because of their advantages like simple to implement, reduction in computation time, a fast and near global optimal solution .

An approach for the optimal power flow problem in a deregulated power market using Bender's decomposition has been presented[7-9].The other methods to find the solution for OPF problem have been discussed [10-13]. Based on the review above, it reveals that there is a single stage initialization process. But, in this paper the initialization is done in two stages and also it gives better solution with less number of generations which results in the reduction of the computation time. Numerical results are carried out on a standard IEEE 30 bus system. The OPF results like bus voltages, active power generation, generation cost ,emission, power loss and computation time has been compared for TSIFPA and FPA. From the results, it can be observed that the proposed algorithm gives better solution than existing algorithm .

The remaining portion of the paper is organized as follows: Section II discusses the OPF problem formulation with different objective functions. Section III gives the overview of the proposed algorithm . Section IV demonstrates the effectiveness of proposed algorithm through numerical example and finally, conclusion is drawn in Section V.

II. OPF PROBLEM FORMULATION

In its general form, the OPF problem can be mathematically represented as

$$\text{Minimize} \quad f(x,u) \tag{1}$$

subjected to

$$g(x,u) = 0 \tag{2}$$

$$h_{\min} \le h(x,u) \le h_{\max} \tag{3}$$

where

$f(x,u)$ is the objective function.

x is the vector of dependent variables

u is the vector of independent variables

$g(x,u)$ represents equality constraints

$h(x,u)$ represents inequality constraints

In this article, minimization of fuel cost, emission and total power loss are considered as an objective functions to examine the performance of the proposed algorithm. The optimal solution must satisfy the equality and inequality constraints. The mathematical expressions for total fuel cost function, emission and total power loss are given in Eqn.(4)-(6) respectively.

$$F(P_{gi}) = \sum_{i=1}^{ng} (a_i + b_i P_{gi} + c_i P_{gi}^2) \ \$/h \tag{4}$$

$$E(P_{gi}) = \sum_{i=1}^{ng} (\alpha_i + \beta_i P_{gi} + \gamma_i P_{gi}^2) \ ton/h \tag{5}$$

$$P_{loss} = \sum_{k=1}^{nl} g_k (V_i^2 + V_j^2 - 2V_iV_j \cos(\delta_i - \delta_j)) \; MW \quad (6)$$

where

a_i, b_i & c_i are cost co-efficient of i^{th} generator.

α_i, β_i & γ_i are emission co-efficient of i^{th} generator.

P_{gi} is the generation of the i^{th} generator.

ng is the number of generator buses.

nl is the number of lines.

g_k is the conductance of k^{th} line.

III. OVERVIEW OF PROPOSED ALGORITHM

In this paper, a two stage initialization[14] based flower pollination algorithm (TSIFPA) has been presented. It tries to approach the target in an optimal manner for finding the optimal solution to any mathematical optimization problem. The major stages of the proposed algorithm are briefly described as follows:

The population is generated by using the following equation

$$x_{i,j} = x_j^{\min} + rand(0,1) \quad (x_j^{\max} - x_j^{\min}) \quad (7)$$

where $i = 1, 2,.., ps$; $j = 1, 2,.., ncv$.

ps = population size.

ncv = number of control variables.

$x_j^{\min}$ & $x_j^{\max}$ are the lower and upper bounds of j^{th} control variable.

rand (0,1) is a uniformly distributed random number between 0 and 1.

The two stage initialization process provides better probability of detecting an optimal solution to the power flow equations that would globally minimize a given objective function. In the first stage, initial population is generated as a multi-dimensional vector of size (*spv* × *ncv)*. Evaluate the value of objective function for each string in the population vector and select the best string from the population vector corresponding to minimum function value. Repeat the procedure for number of population vectors (*n*). In the second stage, combine all the best strings to form multi-dimensional vector of size (*n* ×*ncv)* and this new population is used for evolutionary operations. In flower pollination algorithm (FPA) proposed by Xin She Yang[15,16], each flower changes its position according to its constancy and the previous positions in the problem space. The individual best and global best is calculated during iterative process till the stopping criteria satisfied. The flower constancy is updated using the Eqn.(8)-(9).

Local pollination and global pollination is controlled by a switch probability p ∈ [0, 1].

In the global pollination step, flower pollen gametes are carried by pollinators such as insects, and pollen can travel over a long distance because insects can often fly and move in a much longer range. The inertia weight is updated by using the following equation

$$x_i^{t+1} = x_i^t + L\left(x_i^t - g_*\right) \quad (8)$$

where $L \sim \dfrac{\lambda\Gamma(\lambda)\sin(\pi\lambda/2)}{\pi}\dfrac{1}{S^{1+\lambda}}$

x_i^t = Solution vector x_i at iteration t

g_* = Current best solution

$\Gamma(\lambda)$ = Standard Gamma function

Due to physical proximity and other factors such as wind, local pollination can have a significant fraction p in the overall pollination activities.

$$x_i^{t+1} = x_i^t + \varepsilon\left(x_j^t - x_k^t\right) \quad (9)$$

where

x_j^t and x_k^t are pollen from different flowers of the same plant species. This essentially mimics the flower constancy in a limited neighborhood. Mathematically if x_j^t and x_k^t come from the same species or selected from the same population, this equivalently becomes a local random walk if ε is drawn from a uniform distribution in [0,1].

IV. RESULTS AND DISCUSSIONS

In this section, a standard IEEE 30-bus system [17] has been considered to demonstrate the effectiveness and robustness of proposed TSIFPA. In 30-bus test system, bus 1 is considered as slack bus, while bus 2, 5, 8, 11 and 13 are taken as generator buses and other buses are load buses. A MATLAB program is implemented for the test system on a personal computer with core2duo processor and 2 GB RAM. An analysis has been carried out to study the effect of algorithm parameters on the solution of a power flow problem. Based on the analysis, the input parameters of FPA and TSIFPA for the test system are given in Table I.

The solution for the OPF problem with different objective functions are obtained using FPA and TSIFPA. Table II summarizes the OPF results of both the methods for cost minimization. The OPF results of both the methods for emission and losses minimization are given in Table III and Table IV respectively. The convergence characteristics comparison of the test system using FPA and TSIFPA for cost, emission and losses minimization are shown in Fig.1-Fig.3 respectively.

TABLE I. INPUT PARAMETERS FOR IEEE 30 BUS SYSTEM

Optimization Method	Parameters	Quantity
FPA & TSIFPA	Population size	50
	Number of iterations	100
	Probability vector	0.8
	lambda	$1 \le \lambda \le 3$

From Table II- Table IV, it is observed that the control variables obtained using proposed TSIFPA is superior than FPA. Also, the computing time obtained using proposed algorithm is less than FPA. Further, the iterative process begins with minimum function value and the change in function value from initial to final is less which indicates convergence rate is fast for proposed TSIFPA method than FPA as shown in the Fig.1 to Fig.3. This is because of best strings selected during the initialization which is known as two stage initialization adopted in the proposed method and evolutionary operations are performed on these best strings.

TABLE II. COMPARISION OF OPF SOLUTION FOR COST MINIMIZATION

Control Variables	FPA	TSIFPA
PG1(MW)	178.695	177.87
PG2(MW)	52.281	48.450
PG5(MW)	20.109	21.067
PG8(MW)	16.975	21.925
PG11(MW)	12.253	11.114
PG13(MW)	12.599	12.134
VG1(p.u.)	1.1	1.1
VG2(p.u.)	1.081	1.018
VG5(p.u.)	1.055	1.058
VG8(p.u.)	1.049	1.081
VG11(p.u.)	1.019	1.1
VG13(p.u.)	1.022	0.962
TAP_{6-9}(p.u.)	0.920	0.973
TAP_{6-10}(p.u.)	1.051	0.931
TAP_{4-12}(p.u.)	0.944	0.9
TAP_{28-27}(p.u.)	1.001	0.932
Q_{C10}(MVar)	15.464	20.781
Q_{C24}(MVar)	19.926	13.856
Cost($/h)	**801.692**	**800.834**
Emission(ton/h)	0.371	0.368
P_{Loss} (MW)	9.512	9.160
Time (Sec)	21.092	13.772

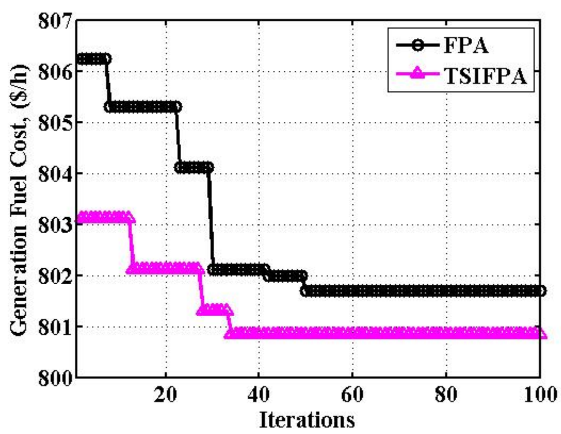

Fig.1 Comparison of convergence characteristics for cost minimisation.

TABLE III. COMPARISION OF OPF SOLUTION FOR EMISSION MINIMIZATION

Control Variables	FPA	TSIFPA
PG1(MW)	69.878	62.792
PG2(MW)	66.09	70.722
PG5(MW)	50	49.472
PG8(MW)	31.366	34.820
PG11(MW)	30	30
PG13(MW)	40	40
VG1(p.u.)	1.018	0.9687
VG2(p.u.)	1.015	0.9
VG5(p.u.)	1.019	0.942
VG8(p.u.)	1.1	1.052
VG11(p.u.)	0.9	1.045
VG13(p.u.)	1.1	1.098
TAP_{6-9}(p.u.)	0.932	0.978
TAP_{6-10}(p.u.)	0.9	0.948
TAP_{4-12}(p.u.)	0.927	0.922
TAP_{28-27}(p.u.)	0.931	0.908
Q_{C10}(MVar)	26.403	22.417
Q_{C24}(MVar)	5	22.895
Cost($/h)	939.054	949.876
Emission(ton/h)	**0.206**	**0.205**
P_{Loss} (MW)	3.933	4.406
Time (Sec)	24.718	14.872

TABLE IV. COMPARISION OF OPF SOLUTION FOR POWER LOSS MINIMIZATION

Control Variables	FPA	TSIFPA
PG1(MW)	53.854	51.998
PG2(MW)	78.483	79.623
PG5(MW)	50	50
PG8(MW)	34.909	35
PG11(MW)	29.516	30
PG13(MW)	39.958	40
VG1(p.u.)	1.092	1.051
VG2(p.u.)	1.021	1.047
VG3(p.u.)	1.062	1.028
VG8(p.u.)	1.056	1.035
VG11(p.u.)	0.921	1.051
VG13(p.u.)	1.086	1.082
TAP_{6-9}(p.u.)	1.005	0.970
TAP_{6-10}(p.u.)	1.057	0.954
TAP_{4-12}(p.u.)	1.02	0.995
TAP_{28-27}(p.u.)	1.024	0.945
Q_{C10}(MVar)	15.113	16.597
Q_{C24}(MVar)	14.767	6.678
Cost($/h)	963.715	967.139
Emission(ton/h)	0.207	0.207
P_{Loss} (MW)	**3.322**	**3.221**
Time (Sec)	23.109	12.399

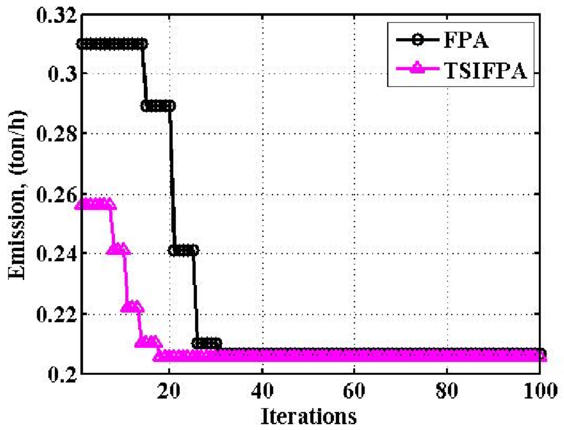

Fig.2 Comparison of convergence characteristics for emission minimisation.

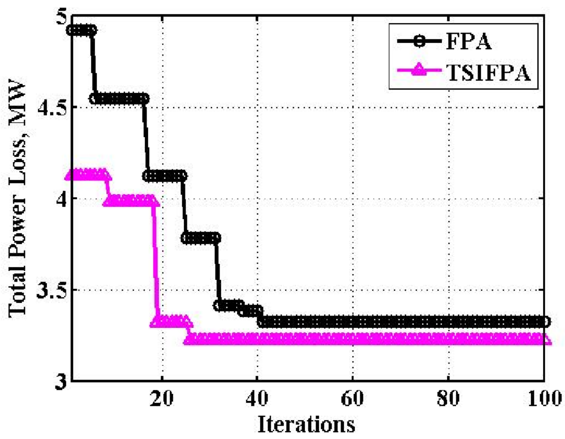

Fig.3 Comparison of convergence characteristics for loss minimization.

V. CONCLUSION

In this paper, a two stage initialization based flower pollination algorithm has been proposed to solve optimal power flow problem with different objective functions. The OPF results obtained for test system using the proposed TSIFPA and existing FPA are compared. The observations reveal that the control variables obtained using proposed TSIFPA is superior than FPA. Because of two stage initialization, the computing time obtained using proposed algorithm is less than FPA. Further, the iterative process begins with minimum function value and the change in function value from initial to final is less which indicates convergence rate is fast for proposed TSIFPA method than FPA.

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