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Optimal Power Flow Using Hybrid DA-APSO Algorithm in Renewable Energy Resources

C. Shilaja[a*], K. Ravi[b]

[a]*School of Electrical Engineering, VIT University Vellore, Tamilnadu 632014, India*

[b]*School of Electrical Engineering, VIT University Vellore, Tamilnadu 632014, India*

Abstract

Optimal Power Flow (OPF) is a nonlinear and highly constrained optimization problem. This research presents a hybrid metaheuristic based optimization method, Dragonfly Algorithm (DA) with Aging Particle Swarm Optimization (APSO) for handling OPF problem. The proposed hybrid algorithm is implemented to rectify OPF problem and to obtain the optimal values of power system control variables. The fuel cost minimization, voltage profile deviation and power loss minimization are the major objectives of OPF problem. The effectiveness of proposed hybrid algorithm is experimented in IEEE 30-bus system. The output obtained is tested using wind energy system by power loss constraints. The major difficulties of conventional methods are they required linearization, slow in operation and prediction of optimum point of operation. The proposed method is compared with the existing algorithms and the simulation yields better results.

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Keywords: Optimal Power Flow; Voltage Profile Deviation; Power Loss Minimization; IEEE 30-bus system.

1. Introduction

Optimal Power Flow (OPF) problem is a decisive challenge in power system. OPF is the task of controlling and planning secure operation of renewable energy resources [1]. The OPF plays a vital role in minimization of cost factor for providing efficient power system operation. In recent years, renewable energy system has the challenge of erratic amount of power generation system. The key objective of OPF is to determine the finest way to instantaneously operate a power system. The optimum solution denotes the minimization of operating cost of power system. The OPF solution methods are classified into two types. They are predictable and artificial intelligence method. Some of the conventional OPF techniques are linear programming, Gradient Methods, Quadratic

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programming, Newton-Raphson, Non Linear programming and Interior point. The conventional methods faced various drawbacks [3]. They required linearization, less convergence, weak in handling qualitative aspects and it was found that slow operation was carried out when there was large number of variables.

The traditional methods were struck at prediction of optimal minimum point of operation. To overcome the drawbacks of prevailing methods of solving OPF, non-deterministic or Artificial Intelligence (AI) method was introduced. AI method optimizes the global or near-global optimal solution. The major advantages of these methods are i) tackling several qualitative constraints ii) many optimal solutions in one execution iii) solving multi-objective optimization problems and iv) global optimum solution [4]. The met heuristic algorithms are being employed as a sub optimal solution to optimization problem. There are Tabu search [2], simulated annealing, Evolutionary computation, Ant colony optimization, etc. [5].OPF based on Bat optimization algorithm was developed to determine the optimal values of control variables involved in OPF including both inequality and equality constraints. Bat algorithm operates on the principle of echolocation of bats which is utilized to update their location. Echolocation is a sequence of high-sounding ultrasound waves emanated to generate echoes. Such echoes are reflected with latency and altered sound limit that aids bats to locate a prey [6]. OPF based on Ant Colony Optimization (ACO) works on the basis of behavior of ants' which utilize a strange communication using pheromone dropped on the path. This approach helps other ants to follow the same shortest path [7, 8].Dragonfly Algorithm (DA) was proposed for OPF which deals with swarming behavior of dragonflies. It is based on separation, alignment and cohesion, desirability to food and diversion from adversaries. The exploration and exploitation parameters were designed to predict global optimization. The average fitness of dragonflies was applied to find the progress of fitness of the entire swarm in optimization. DA algorithm was used to solve both the binary and multi-objective problems [11]. Newton Raphson oriented hybrid Particle Swarm Optimization (PSO) was developed to handle nonlinear problems with continuous variables and finding out the optimal groupings ofcontrol variables. PSO is a metaheuristic algorithm that makes few assumptions based on the problem to be optimized and probably searches huge spaces of candidate solutions. The objective function is the total generation cost function with generator constraints comprising active and reactive power generation ranges along with valve loading effects [10].

In this paper, the hybrid Dragonfly Algorithm (DA) with Aging Particle Swarm Optimization (APSO) is deployed which is based on fixed swarm behavior of flies while exploring food. APSO cover more uncertain space in reduced time of computation to explore possible solution and improve the selection of leader to attract swarm towards better optimum solutions.

2. Problem Formulation

In power system the vital role of OPF is to minimize the particular objective function which satisfies the equality and inequality constraints

$$\text{minimize} \quad \text{of } f(a,b)$$

$$\text{subjected to} \begin{Bmatrix} E(a,b)=0 \\ I_{E_l} \le IE(a,b) \le I_{E_u} \end{Bmatrix} \tag{1}$$

Where $f(a,b)$ is the objective function, $E(a,b)$ denotes equality constraints of the *i*th generator, $IE(a,b)$ represents inequality constraints and I_{E_u}, I_{E_l} are the higher and lower levels of inequality constraints of the *i*th generator.

2.1. Objective Functions

The major objective function to mitigate OPF problem is given as follows.

i) Reduction of fuel cost

The G_1 represents the total fuel cost and the minimization of fuel cost is expressed as,

$$G_1(u,v)=\sum_{i=1}^{NG} bf_i(\$/h) \tag{2}$$

Where bf_i represents the fuel cost of generator i.

$$bf_i = k_i + l_i P_{G_i} + b_i P_{G_i}^{\;2}(\$/h) \tag{3}$$

k_i, l_i and b_i are the cost coefficients of *i*th generator

ii) Voltage profile deviation

The total voltage deviations reduction in all PQ buses is the major objective of voltage profile deviation [5]. The two-fold objective function has been considered that is related to both fuel cost minimization and voltage profile improvement is given by as,

$$G_2(u,v)=\sum_{i=1}^{NG} f_i(\$/h)+V_1\sum_{i\in NL}\left|P.U-V_i\right| \tag{4}$$

where,
$G_2(u,v)$ is total profile deviations
f_i is the fuel of the *i*th generator
V_1 is suitable weighing factor chosen by user.

iii) Power loss minimization

The P_1 represents the Overall power loss is evaluated as follows,

$$P_l=\sum_{k=1}^{N_1}\frac{r_k}{r_k^{\;2}+x_k^{\;2}}\left[V_i^2+V_j^2-2V_iV_j\cos(\theta_i-\theta_j)\right] \tag{5}$$

N_1 denotes the transmission lines count, r_k is the resistance and x_k is the reactance of k[th] transmission line that relates i[th] and j[th] bus, V_i , V_j are the voltage magnitudes and θ_i, θ_j are the voltage angles for the bus i and j.
Without wind power constraints, the objective function is given defined by $f_i(d_i)$ which is the minimum cost function of the DA-APSO algorithm. The wind power is used to reduce the power demand. The proposed algorithm is tested in wind energy system to attain performance effects of the hybrid algorithm. The major objective is to optimize the power flow and reduce power loss produced in both fuel and wind energy constraints.

$$f(d)=\sum_{i}^{N_d} f_i(d_i)+B+T \tag{6}$$

Where B and T are the loss coefficients of the generator

2.2 Dragonfly Algorithm

Dragonfly forms a small group and fly towards different direction covering vast area in search of food known as exploration phase and shifts to other places known as exploitation phase. Five steps that are followed in dragonfly behaviour are separation, alignment, cohesion, attraction towards food and distraction towards enemy. Separation alludes to stationary collision prevention of flies from others in the neighbouring region. Alignment refers to speed coordination of flies among others in neighbouring area. Cohesion is inclination of individuals towards the focal point of the mass of the area. In order to survive, every individual will move in the direction of food as well as divert away from enemies. Based on these five factors, various exploration and exploitation behaviors can be obtained in optimization.

2.3 Aging Particle Swarm Optimization (APSO)

According to APSO the swarm leader ages within a particular lifespan period. The lifespan is extended with respect to leader's leading capability. Newly generated particles are replaced as leaders when lifetime of the swarm leader is exhausted [13]. The swarm leader is represented by

$$\vec{x}_{leader}(\vec{x}_{leader}, \vec{x}_{leader}, \ldots, \vec{x}_{leader}) \quad (7)$$

This algorithm is useful in handling the premature convergence and provides rapid converging characteristics of PSO. The steps involved in this algorithm are (i) initialization which sets the particle positions and velocity in search space, (ii) leader updating is done if performance of new particle is higher than the current leader, (iii) regulating the life span of leader based on leading capability, (iv) new particle creation when the current leader's life is over, (v) estimating the new particle performance against the current leader's leading capability and (vi) Finding the best solution. The leader denotes the best solution created by particles throughout the lifetime of the leader.

3. Hybrid DA-APSO

The APSO decides and challenges the leader when its life span is exhausted. The DA provides exploration and exploitation phase. By combining the new velocity and position vectors decided by APSO with exploration and exploitation phase of DA the targeted optimum solution could be attained. The hybrid algorithm for OPF using DA-APSO is given by as,

Step 1: Read power system data

Step 2: By setting iteration count, initialize population of 'n' dragonflies

Step 3: Initialize step vector and set iteration count as 1

Step 4: Objective functions are evaluated and food and enemy source are identified.

Step 5: Update and compute values of a,b,c,d,e by equations as

Separation 'a_i' is given as,

$$a_i = -\sum_{j=1}^{N} x - x_j \quad (8)$$

x denotes the location of present individual, x_j is the location of individual in the neighbouring region and N is the count of individuals in the neighbouring region.

Alignment 'b_i' is expressed as,

$$b_i = \sum_{j=1}^{N} \frac{V_j}{N} \quad (9)$$

V_j - Velocity of j^{th} neighbouring individual

Cohesion is given by as,

$$c_i = \sum_{j=1}^{N} \frac{x_i}{N} - x \quad (10)$$

Attraction towards food 'd_i' is evaluated by,

$$d_i = x^+ - x \quad (11)$$

x, x^+ represents the location of present individual and food

Distraction towards enemy is given as 'e_i' as,

$$e_i = x^- + x \quad (12)$$

x, x^- - represents the location of present individual and enemy

The step vector and position vector is given by as,

$$\Delta X_{f+1} = (aa_i + bb_i + cc_i + dd_i + ee_i) + w\Delta X_f$$
$$X_{f+1} = X_f + \Delta X_{f+1} \quad (13)$$

If no neighbouring solution, the dragonfly position is updated by levy flight.

$$X_{f+1} = X_f + levy(d) * X_f \quad (14)$$

Step 6: With respect to at least one neighbourhood the velocity and position vector calculated by new velocity and position vector equation of APSO. Else update position vector using levy lift equation.

Step 7: After new positions are decided, set iter = iter+1. If iter value is less than maximum iter value then go to step 4. Else stop process.

4. Performance evaluations

The hybrid DA-APSO algorithm has been employed in IEEE 30 bus test system. It contains 6 generators at bus 1, 2, 5, 8, 11, 13 and 4 transformers with tap ratios. In bus 10, 12, 15, 17, 20, 21, 23, 24 and 29 shunt VAR compensation has been provided. Bus 1 acts as slack bus. The bus voltage is confined within the range of 0.95-1.05 per unit. Number of trails considered in DA-APSO was 20. The parameters chosen for optimization were power loss minimization, fuel cost minimization and voltage deviation. In Table 1, the proposed method and the traditional methods are compared in terms of cost of fuel and it is less for DA-APSO than other methods. Table 2 lists the values obtained from the IEEE 30 bus system considering its constraints and also compared the cost of fuel of DA-APSO method with other conventional metaheuristic methods.

Table 1.Evaluation of fuel cost of different optimization methods.

Methods	Fuel cost
DA-APSO	**802.63**
DA[12]	803.65
APSO[13]	803.6
ABC[9]	803.78
TLBO[2]	804.78

Table 2. IEEE 30 bus system results.

Control variables in p.u.	Improved GA [17]	PSO[16]	DA-APSO
P_{G-1}	1.775094	1.7695	1.7453
P_{G-2}	0.48722	0.4783	0.4873
P_{G-5}	0.21454	0.2120	0.2027
P_{G-8}	0.20954	0.2178	0.2110
P_{G-11}	0.11768	0.1192	0.1235
P_{G-13}	0.12052	0.1092	0.1133
V_1	0.081	1.0937	1.023
V_2	1.063	1.0703	1.023
V_5	1.034	1.0692	1.037
V_8	1.038	1.0302	0.0912
V_{11}	1.100	1.0293	1.0092
V_{13}	1.055	1.0116	0.982
T_{6-9}	1.000	1.0982	0.9112
T_{6-10}	0.975	0.0452	0.0112
T_{4-12}	0.975	0.0122	0.0311
T_{28-27}	1.000	0.0456	0.0342
Q_{c-10}	0.001	0.0356	0.0124
Q_{c-12}	0.007	0.0498	0.0311
Q_{c-15}	0.019	0.0145	0.0300
Q_{c-17}	0.024	0.0582	0.0101
Q_{c-20}	0.015	0.0489	0.067
Q_{c-21}	0.022	0.0239	0.051
Q_{c-23}	0.047	0.0111	0.032
Q_{c-24}	0.047	0.032	0.0144
Q_{c-29}	0.024	0.052	0.012
Fuel cost($/h)	805.805	805.65	**802.63**

Table 3 highlights the cost of fuel and voltage deviation and two fold objective function value of the proposed method and the traditional methods. The cost of fuel and voltage deviation and two fold objective function of DA-APSO are lesser than other methods.

Table 3. Fuel cost and voltage deviation of proposed and existing methods.

Methods	Fuel cost	Voltage deviation	Two fold objective function
DA-APSO	**802.63**	**0.1164**	**812.4526**
DA[12]	803.65	0.1272	816.4527
APSO[13]	803.6	0.0891	825.2893
ABC[9]	803.78	0.1243	822.3452
DE[14]	805.26	0.1357	818.8319
TLBO[15]	803.78	0.0945	813.2345

4.1. Fuel cost minimization

It was considered that the cost function for all 6 generators in quadratic form. A provided minimum total fuel cost of 800.6594 $/h. Figure 1 depicts the fuel cost minimization of DS-APSO and the existing techniques and it is evident that DA-APSO provides better fuel cost minimization

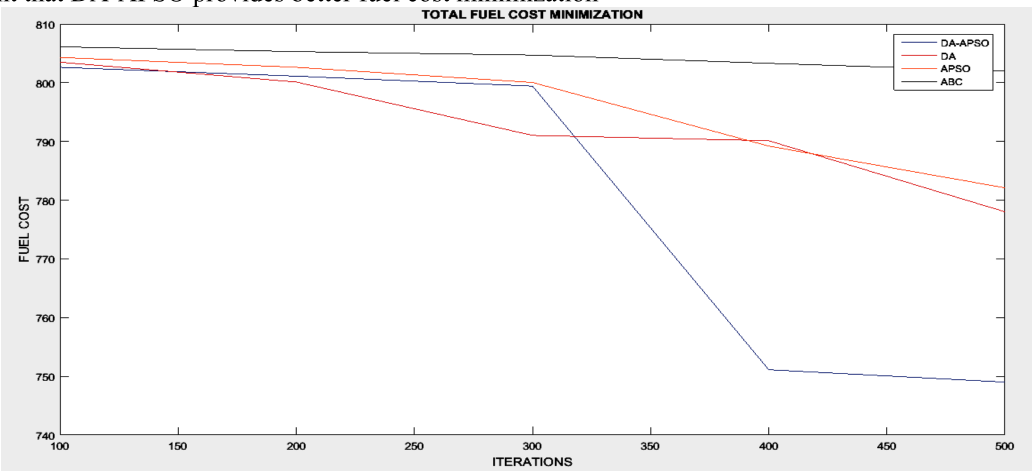

Fig. 1. Fuel cost minimization of DA-APS

4.2. Power loss minimization

The mean total active power loss of DA methods was 3.1455 MW, with high total active loss. Figure 2 illustrates the power loss minimization of DA-APSO and other methods. In the proposed method, the active power loss is reduced to 3.003 MW.

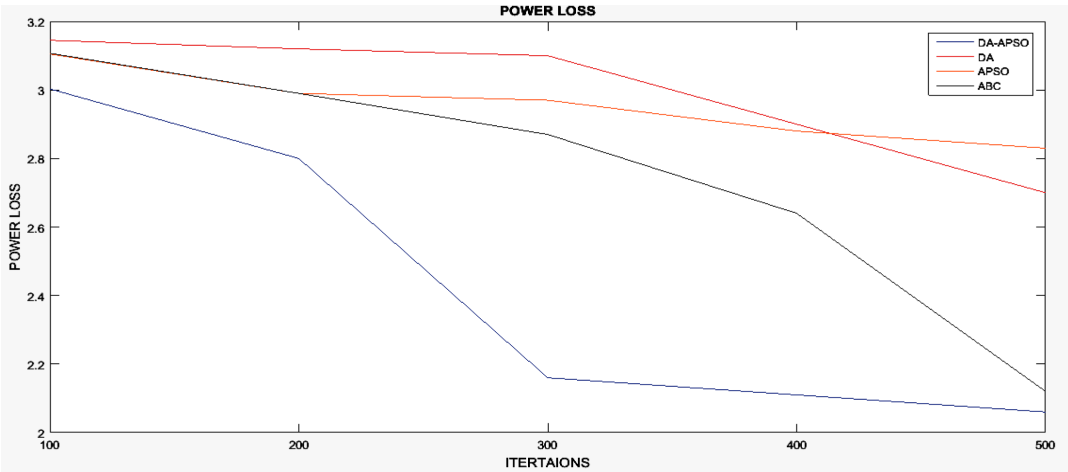

Fig. 2.Power loss minimization of proposed and existing methods.

4.3. Voltage deviation

Figure 3 depicts the performance of the proposed DA-APSO and the existing methods for voltage deviation. The power loss is reduced to about 3.003 MW using proposed method. By comparing with appropriate wind energy test system and considering active power loss of proposed method, deploying wind energy system in the proposed method further reduces the power loss by 3.002 MW which is given in figure 4.

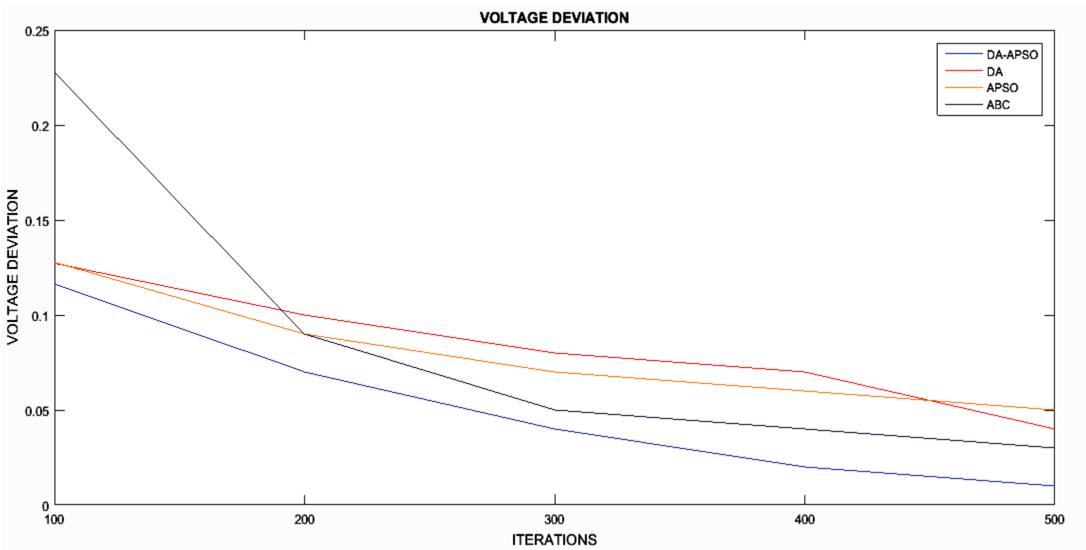

Fig. 3. Voltage deviation of DA-APSO and existing methods

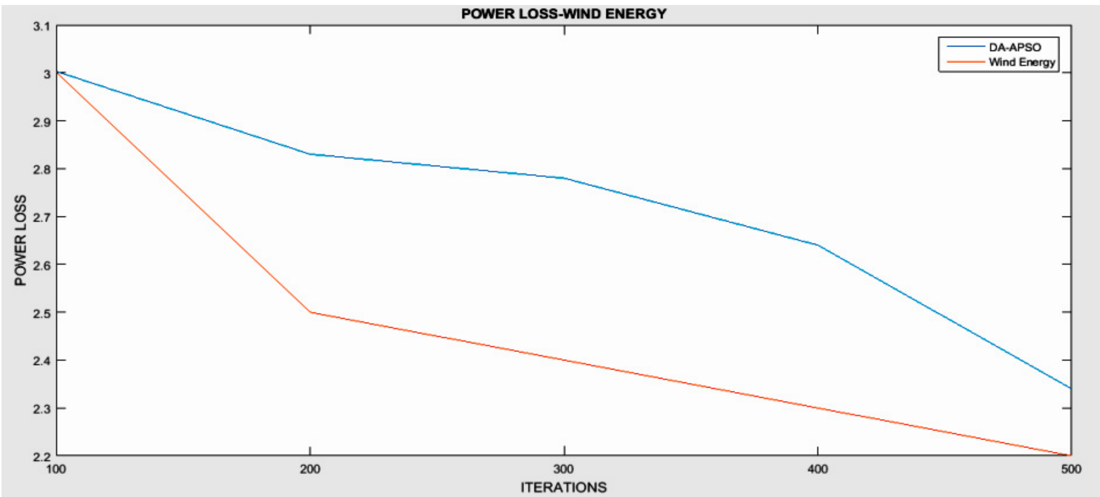

Fig. 4. Power loss in DA-APSO with wind energy system.

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5. Conclusion

By using hybrid DA-APSO algorithm the OPF problem has been reduced. The minimization of cost, loss of power and progress of voltage profile is performed and tested in IEEE 30 bus test system. The simulation of outcomes reveals that DA-APSO performs better than the existing optimization techniques. The power loss occurred in proposed method was tested by comparing with wind energy system. The future scope of this study is advancement of proposed algorithm by alternate test system like IEEE 118 test system and adapting renewable energy resources for further fuel cost reduction.

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