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Dispatch of Multiarea System with Tie Line Constraints using Modified Particle Swarm Optimization

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Abstract: This paper presents the dispatch of multiarea system using the novel algorithm consisting of modified particle swarm optimization (PSO). The proposed algorithm uses PSO as a base level search and the solution obtained is improved using deterministic simplex search method after local level search. Economic emission dispatch of multiarea system including tie line constraints is considered to check the robustness of the proposed method. Transmission losses are also included to have the practical aspect in the problem. Reducing fuel cost and pollutants' emissions simultaneously results in complex multiobjective problem which is converted into single objective using the method of price penalty factors. The effectiveness of the proposed method is tested on a test system consisting four areas, sixteen generator with six tie lines. Special case of sale and purchase of power from external power sources is also included in the paper. The comparison of the results obtained using proposed algorithm with the available literature is done to show the robustness of the proposed method.

Keywords: Dispatch of Multiarea System (DMS), Particle Swarm Optimization (PSO), Price Penalty Factors (PPF), Simplex Search Method (SM).

I. INTRODUCTION

The electric power industry is usually interconnected to have the advantage of reducing the overall fuel cost, pollutants' emissions and transmission losses. This study of interconnected system is generally called as the dispatch of multiarea system (DMS). DMS also helps in maintaining the reliability, stability of power supply, operation under emergency period and lowering the reserve sharing capability in the whole region. The areas which are not sufficient in meeting their own demand need reserve sharing from other areas. Thus, DMS system helps in improving the overall performance of power supply industry. Each area in the multiarea system has its own set of generators, which are interconnected by tie lines for sharing the overall demand of the region. For DMS problem, large interconnected power system is decomposed into small areas or zones based on criteria's such as geographical locations, size of the power system, network topology, etc. Hence the solution to such problem is to determine the power that can be economically and environmentally generated and transferred in these areas without violating tie-line constraints and other network constraints. If the demand varies in any area, it is covered equally by all the generators in connected areas with change in the power flow on the transmission lines. The power dispatch between the areas must not violate the power balance constraint in the whole system as well as generator and tie line limit constraints. In DMS, the individual power generation is not balanced within its own area only because of the presence of the power export and import to other areas also [1,2]. Hence, the DMS is considered as the large scale optimization problem.

This interchange of power between different areas led to the problem of deregulation. Also the scheduling of power transactions in deregulated environment give rise to the formation of market structures in the electric utility systems. The deregulated environment emphasizes the potential for competition in the electricity market. Each participating utility try to operate their generating plant with maximum profit on load demand, efficient operation and minimum impact of environmental pollution. This leads to find the optimal power distribution between the areas such that emissions are controlled to maximum extent and overall cost of fuel is reduced. Thus give rise to multiobjective problem, but with conflicting objectives.

Many researchers have worked in the field of economic environmental issue in multiarea systems by taking fuel cost and pollutant emissions as separate objectives [3] i.e, giving advantage to one objective at one time. The losses are also not included while solving for economic/ pollutants' emissions dispatch in multi area system. In this paper, we are considering this non linear optimization problem by collectively reducing the pollutants' emissions and fuel cost. The transmission losses are also considered in the paper which is necessary to have practical aspect in the problem considered.

Chen and Wang [4] solves the multiarea dispatch problem using PSO and calculating minimum emissions and fuel cost separately for the whole region. Other researchers used evolutionary methods like Differential Evolution (DE) and modified PSO_TVAC [5] considering the objective of cost only along with the effect of variation of power flow on tie lines. [6] uses the Hopfield neural network(HNN) approach to solve the DMS problem.[7] also compares the evolutionary methods like Particle

Swarm Optimization (PSO), Real-coded Genetic Algorithm (RGA), DE and Covariance Matrix Adapted Evolution Strategy (CMAES) on multiarea problem in terms of fuel cost only. Improved PSO (IPSO) used by [8] on multiarea system finds the optimal value of power generation and power flow on tie lines by providing a better balance between cognitive and social behavior of the swarm. A decomposition-coordinating method based on Lagrange's function [9] solves the multiarea dispatch problem using parallel processing technique. Due to the complexity of the multiarea problem, conventional methods [10] which use derivatives and gradients alone like lambda iteration method, Newton method, gradient method and linear programming method are not able to locate the global solution in DMS [11]. Hence, the direct search methods [12] are used alongwith the modern optimization techniques, which convert the simple optimization problem into the hybrid optimization. This is done to improve the results when compared with other available methods. The direct search method includes simplex search method (SM), pattern search method, Powell's method and others. These are generally called as derivative free methods as gradient of the function is not required for the optimal solution. Among these methods, DE, PSO and their modifications are popular due their fast convergence, easy implementation and consistency. But alone, they will not be able to give global optimal solution.

Thus, in this paper, the novel hybridization of PSO and simplex search method (HPSOSM) is done. The stochastic method, PSO is used as base level search and deterministic method, SM is used for local level search, which improves the solutions to reach the global optimum or near global optimum point. This combination of simplex with PSO also overcomes certain limitations of PSO like premature convergence and stagnation in the solution when the number of generations increases. In addition to this proposed optimization method, choice of decision making method also plays a vital role in the process of fast convergence for better optimal solution. Different decision making techniques like weighted search (WS), price penalty factors (PPF), fuzzy set theory etc. are available [13]. We are using PPF as decision making method along with the proposed hybrid combination of PSO and SM. The PPF [14] is defined as the proportion of fuel cost to emission values with different approaches as Min-Min, Max-Max, Max-Min and Min-Max, which give rise to maximum four different solutions and hence become very easy to decide the best one out of these. PPF converts the multiobjective optimization problem of reducing the conflicting fuel cost and emission objectives into scalar optimization problem. The proposed hybrid method is effectively tested on four areas sixteen generator system connected with six tie lines for multiarea system, while satisfying its all equality and inequality constraints.

II. Problem Formulation

The DMS is solved to fulfill the objectives of reducing the overall fuel cost from all the areas as well as pollutants emissions. These objectives are conflicting and non-commensurable in nature which must satisfy the system constraints to get the optimal solution. Each area has its own set of generators, which are connected to each other through tie lines. Transmission Losses are also considered to include the practical impact in the problem.

A. Minimization of Objective Function:

Mathematically, the objective function consist equation for both fuel cost and pollutant's emissions. These conflicting multi-objective equations are converted into single objective using price penalty factors (h) as,

$$Minimize\ Objective\ Function, F_{Tk} = F_C + h_k(E_T) \quad (k = 1,2,3,4) \tag{1}$$

$$Fuel\ cost, F_C = \sum_{i=1}^{M}\sum_{j=1}^{G}(a_{ij}P_{ij}^2 + b_{ij}P_{ij} + c_{ij}) \tag{2}$$

$$Power\ Transmission\ Cost, PT_C = \sum_{m=1}^{M}\sum_{n=1}^{M} f_{mn}P_{Tmn} \tag{3}$$

$$Total\ Operating\ Cost, OC_T = F_C + PT_C \tag{4}$$

$$Total\ Pollutants'\ Emissions, E_T = \sum_{i=1}^{M}\sum_{j=1}^{G}(\alpha_{ij}P_{ij}^2 + \beta_{ij}P_{ij} + \gamma_{ij}) \tag{5}$$

$$h_1 = \frac{F_C(P_{min})}{E_T(P_{max})} \tag{6}$$

$$h_2 = \frac{F_C(P_{min})}{E_T(P_{min})} \tag{7}$$

$$h_3 = \frac{F_C(P_{max})}{E_T(P_{max})} \tag{8}$$

$$h_4 = \frac{F_C(P_{max})}{E_T(P_{min})} \tag{9}$$

Where G is the total number of generators committed to the operating system in M areas, h is the price penalty factor, a_{ij} , b_{ij} , c_{ij} are the fuel cost coefficients and α_{ij} , β_{ij} , γ_{ij} represents the pollutant's emission coefficients of the j^{th} generator in i^{th} area. P_{ij} represents the real power produced by j^{th} generator of i^{th} area. f_{mn} represents the transmission cost coefficient and P_{Tmn} is the power flow on tielines from area m to area n, if its value is positive and power flow from area n to area m if its value is negative.

The optimization problem is to minimize (1) by using different values of price penalty factors as given in (6-9).

$$F_{Tk} = min\{F_{T1}, F_{T2}, F_{T3}, F_{T4}\} \tag{10}$$

Here, the value of (10) will become the optimal solution for the DMS problem.

B. System Constraints:

The objective function defined in (1) has subjected to power balance equality constraint throughout the region, generator constraints and tie line constraint. In the multiarea system, the individual area generation is not balanced with its own generation because of the presence of the power export and import to other areas also. Hence, the overall real power generated in the region must be balanced with the overall power demand, total losses and net power flow on transmission lines. Power balance equality constraint can be given,

$$\sum_{j=1}^{M} P_j = P_D + P_L + \sum_{m=1}^{L} P_{Tm} \qquad (11)$$

Where, PD represents total power demand in all areas, PL is the total power loss in the region as given in (12) and PTm is the power transfer on 'T' tie lines between the areas. The loss in transmission line can be expressed by Kron's loss formula as,

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \qquad (12)$$

where, B_{ij}, B_{0i}, B_{00} are the transmission loss coefficients. Generator and tie lines inequality constraints are given as,

$$Generator\ limits,\ P_{j,min} \le P_j \le P_{j,max}; \qquad (13)$$

$$(j = 1,2,\dots,G)$$

$$Tie\ line\ limits,\quad P_{Tm,min} \le P_{Tm} \le P_{Tm,max} \qquad (14)$$

$$(m = 1,2,\dots,T)$$

$P_{j,max}$ and $P_{j,min}$ are the maximum and minimum powers that can be produced by the j^{th} generator in the particular area. $P_{Tm,max}$ and $P_{Tm,min}$ are the maximum and minimum power flow on the '*T*' transmission lines.

III. Implementation Of Proposed HPSOSM On DMS Problem

Recent research shows that the PSO based methods give more promising results in wide variety of multiobjective optimization problems in terms of convergence, robustness and simplicity. In this paper, PSO is hybridized with SM to deal with multiarea dispatch problem.

A. Particle Swarm Optimization:

PSO is a nature inspired stochastic optimization technique developed by Eberhart and Kennedy in 1995, which is inspired from the social behavior of swarms of birds or insects [15, 16]. It is an efficient optimization technique in dealing with large variety of engineering problems. This optimization method starts with a random set of particles in the prescribed search space. These particles adjust its position and velocity during the optimization process to reach the optimal solution. With each iteration, the particle is upgraded by the two values, *pbest* and *gbest*. *pbest* is the optimum solution it has attained so far between all particles, whereas the optimum value accomplished from the total population is a global best and is termed as *gbest*.

Initialization of Swarms:

The number of swarms p_i , is equal to the total number of generating units, *G* in *M* areas plus the total tie lines, *T* interconnecting the *M* areas. N_p is the total number of particles in a swarm.

$$p_i = \begin{bmatrix} P_{11}, P_{12}, \dots, P_{1G}, P_{21}, P_{22}, \dots, P_{2G}, \\ \dots\dots, P_{M1}, P_{M2}, \dots, P_{MG}, P_{T1}, P_{T2}, \dots, P_T \end{bmatrix} \qquad (15)$$

Initial velocity of particles is calculated as

$$v_{pi}(0) = v_{pi}^{min} + r\left(v_{pi}^{max} - v_{pi}^{min}\right) \qquad (16)$$

$$(i = 1,2,\dots,G,T_{12},T_{13},\dots,T_{23},\dots,T)$$

$$(p = 1,2,\dots\dots,N_P)$$

$$where,\ v_{pi}^{min} = -0.5P_{i,min}\ and\ v_{pi}^{max} = +0.5P_{i,max} \quad (17)$$

Initial positions of particle members is calculated as,

$$P_{pi}(0) = P_{i,min} + r\left(P_{i,max} - P_{i,min}\right) \qquad (18)$$

$$(i = 1,2,\dots,G,T_{12},T_{13},\dots,T_{23},\dots,T)$$

$$(p = 1,2,\dots\dots,N_P)$$

$P_{i,min}$ and $P_{i,max}$ are the minimum and maximum limits for generating units and tie lines.

Updation of Velocity and Position of Swarms:

Velocity and position of individual particle is updated as,

$$v_{pi}(k+1) = wv_{pi}(k) + c_1 r_1(k)\left(pbest_{pi}(k) - \right.$$
$$Ppik+c2r2kgbestik-Ppik \qquad (19)$$

$$P_{pi}(k+1) = P_{pi}(k) + v_{pi}(k+1) \qquad (20)$$

$$w = w^{max} - \left(\frac{w^{max} - w^{min}}{iter^{max}}\right) iter \qquad (21)$$

with $w^{min} = 0.4$ and $w^{max} = 0.9$

where, $v_{pi}(k)$ *and* $P_{pi}(k)$ represents the velocity and position of p^{th} particle during k^{th} movement, *w* is weight of inertia, c_1 and c_2 are the acceleration constants usually both are equal to 2, $r_1(k)$ and $r_2(k)$ are the random numbers between (0,1), $iter^{max}$ represents the maximum number of iterations and *iter* is the current iteration number. The updated velocity and position of the particle must satisfy their inequality generator and tie line constraints as given in (13, 14). With different penalty factors, (10) will decide the non-inferior solution against the optimum set of swarm particles.

$$F_{Tp} = min\{F_{Tp1}, F_{Tp2}, F_{Tp3}, F_{Tp4}\} \quad (22)$$

The updated velocity of the particle must satisfy its minimum and maximum inequality constraints as given in Eq. (23)

$$-0.5P_{pi}^{min} \le V_{pi} \le +0.5\, P_{pi}^{max}, \quad (23)$$
$$(i = 1,2, \ldots, G;\ p = 1,2, \ldots, N_P)$$

For the balancing of power demand constraint, one of the generators in each area is selected as dependent generator [11], (5) can be re-written as,

$$\sum_{i=1}^{M} P_{id} = \sum_{i=1}^{M} P_{Di} + \sum_{i=1}^{M} P_{Li} + \sum_{m=1}^{L} P_{Tm} - \sum_{\substack{j=1 \\ j\neq d}}^{G} P_{ij} \quad (24)$$
$$(i = 1,2, \ldots, M;\ j = 1,2, \ldots, G)$$

B. Simplex Search Method:

In 1965, Nelder and Mead proposed this method [12] for finding local minima among a function of several variables. An optimal point is iteratively produced by a sequence of simplexes. To improve the solution obtained from PSO, this method is applied on the G+T+1 best solutions (where, G is the total number of generators and T is the number of tie lines in the region), which act as variables for initial simplex. This method iteratively improves the worst point by different operations as reflection, expansion and contraction as,

1. Determine the best point (n_l), the worst point (n_h) and the next to worst point (n_g) from the initial set of simplex variables.
2. Find centroid (n_{cj}) of all the initial points except the worst point using (25)

   $$n_{cj} = \frac{1}{G}\sum_{i=1, i\neq h}^{G+1} n_{ij} \ (j = 1,2, \ldots, G) \quad (25)$$
3. Find the new reflected point (n_{rj}) as,

   $$n_{rj} = 2n_{cj} - n_{hj} \ (j = 1,2, \ldots, G) \quad (26)$$
4. *If* $f(n_{rj}) < f(n_{lj})$, apply expansion operation as,

   $$n_{new,j} = (1+\gamma)n_{cj} - \gamma n_{hj} \ (j = 1,2, \ldots, G) \quad (27)$$

   where, γ is the expansion factor.
5. *If* $f(n_{rj}) \ge f(n_{hj})$, apply the inside contraction as

   $$n_{new,j} = (1-\beta)n_{cj} + \beta n_{hj} \ (j = 1,2, \ldots, G) \quad (28)$$
6. *If* $f(n_{gj}) < f(n_{rj}) < f(n_{hj})$ apply the outside contraction as,

   $$n_{new,j} = (1+\beta)n_{cj} - \beta n_{hj} \ (j = 1,2, \ldots, G) \quad (29)$$

   where, β is the contraction factor
7. Replace n_{hj} by $n_{new,j}$ and repeat steps 2-6 with new simplex.
8. Continue the iterations to find the optimal solution until the stopping criteria given by (30) is satisfied.

   $$\left[\sum_{i=1}^{G+1} \frac{\left(f(n_{new,i}) - f(n_{ci})\right)^2}{G+1}\right]^{1/2} \le \epsilon \quad (30)$$

   where, ∈ is the termination parameter.

The recommended values for the parameters are γ ≈ 2.0, β ≈ 0.5 and ∈ ≈ 0.001. Final DMS is then calculated using (1) against n_{new} obtained after performing both PSO and SSM.

C. Proposed HPSOSM Algorithm for DMS Problem:

The proposed algorithm combines the stochastic method (PSO) with the deterministic method (SM) to get the overall optimal solution for multiarea dispatch problem. The particle swarm optimization is used as base level search and simplex search method is then used to further improve the solutions to reach the global optimum or near global optimum point.

1. Input the system data, generator and proposed algorithm coefficients.
2. Compute minimum and maximum initial velocities as in (17)
3. Set movement counter k=0
4. Compute of initial velocity and position of swarm particles as in (16, 18)
5. Checking of power demand constraint using (24) by selecting one of the generators as dependent generator in each area.
6. Checking of inequality constraints for velocity using (23) and for position using (13, 14).
7. Calculation of the objectives, $f_p(k) = F_T\left(P_{pi}(k)\right)$ from (22) at various PPF from (6-9) and compute best DMS.
8. Increment movement counter, k=k+1
9. Calculation of the best solution of all the particles, $pbest_{pi}$ and best solution from all the particles, $gbest_i$.
10. Calculation of inertia weight using (21), new velocity using (13) and new position using (14). Checking the velocity constraints from (17) for minimum and maximum values of velocities.
11. Again checking of constraints for this new position and velocity as done in steps 5, 6.

12. Calculation of new values for PPF and objective functions as described in step 7.
13. If ($k \leq iter^{max}$) go to step 9 and repeat for the overall best results from PSO.
14. Input the individual particle's best solution obtained from the PSO to the SM algorithm. The total number of best solutions taken must be one greater than the number of total particles in a swarm and this is considered as the initial simplex.
15. Set simplex iteration counter *itr=1*.
16. Set the worst point (n_h), the best point (n_l) and the next to worst point (n_g) from the initial simplex.
17. Calculate the centroid and reflected points using (25) and (26). After this perform the expansion and contraction operations to get the new optimum points using (27-29).
18. Again checking of power demand constraint as done in step 5 and inequality constraint as done in step 6 for the new points obtained in step 7.
19. IF (convergence criterion using (30) is not met, replace the worst point (n_h) of the initial simplex with the new points obtained and increment the counter *itr=itr+1*.
20. Go to Step 17 and repeat to get best solution until the convergence criteria should be satisfied.
21. Calculate final fuel cost, emissions, power losses and DMS again at different PPF and compute optimal solution as per (10).
22. STOP.

IV. Experimental Results And Discussion

Due to the addition of tie line constraints and combining different areas together makes the multiarea dispatch problem more complex as compared to conventional economic emission dispatch problem of single area system. In this section, the discussion on the experimental verification of proposed method is done. The algorithm is implemented in MATLAB software on an Intel core i3 with 3 GB RAM. Different parameters for the proposed HPSOSM are taken as: Total particles in swarm =10, total members in one particle= number of generators plus tie lines taken in each case, acceleration constants i.e., $c_1 = c_2$ =2, minimum and maximum inertia i.e., w^{min}= 0.4, w^{max} = 0.9, contraction factor (β) = 0.5, expansion factor (γ) = 2.0, tolerance (∈) = 0.001 and maximum number of iterations used = 500. Different cases to be undertaken for the verification of proposed algorithm are,

Case 1: Economic-Emission Dispatch of multiarea system connected by tie lines including transmission losses.

Case 2: Economic-Emission Dispatch, when purchase of power available to area 1 and power available for sale from area 2 with maximum limit of 0.05 MW each at incremental cost of 150 $/MW.

Case 3: Economic-Emission Dispatch, when purchase of power available to area 1 with maximum limit of 0.05 MW at incremental cost of 150 $/MW.

In all the cases mentioned, four areas sixteen generator system connected by six tie lines are considered. Transmission losses are also included in each case to have the practical impact in the problem. The system specifications are taken from [17]. The load demands for the areas are 0.3, 0.5, 0.4 and 0.6 p.u. respectively.

In case 1, the economic-environmental dispatch using the proposed algorithm is evaluated and compared with other cited literature in the references. The comparison is shown in Table 1 and it is observed that the proposed algorithm shows better performance in terms of final fuel cost and pollutants' emissions. Total operating cost, which is the sum of fuel cost and transmission cost, is also presented in the results. It shows the more practical aspect of the case considered and applicability of the proposed algorithm on it. Final combined economic emission dispatch (CEED) calculations are then done by including the cost of fuel and emissions using PPF, according to the Eq. (1).

In case 2, power is purchased from external sources to area 1 and is also available for sale to external sources from area 2 at an incremental cost of 150 $/MW each up to maximum limit of 0.05 p.u. [18]. In case 3, only the purchase power available to area 1 at an incremental cost of 150 $/MW up to maximum limit of 0.05 p.u. is considered.

Table I. Comparison of DMS for Case 1

Unit Power Output (p.u.)	TLBO [3]	PCRO [3]	TV-MOPSO [3]	BB-MOPSO [3]	PSO [17]	IPSO [17]	HPSOSM
P1,1	0.140	0.140	0.139	0.140	0.132	0.120	0.085
P1,2	0.100	0.100	0.100	0.100	0.065	0.100	0.100

P1,3	0.025	0.001	0.030	0.005	0.120	0.090	0.130
P1,4	0.052	0.001	0.060	0.064	0.113	0.120	0.120
P2,1	0.010	0.001	0.055	0.071	0.205	0.250	0.037
P2,2	0.107	0.119	0.028	0.034	0.066	0.120	0.120
P2,3	0.077	0.001	0.005	0.001	0.132	0.121	0.193
P2,4	0.024	0.001	0.037	0.025	0.150	0.010	0.180
P3,1	0.300	0.300	0.300	0.300	0.057	0.013	0.001
P3,2	0.248	0.300	0.249	0.214	0.097	0.013	0.189
P3,3	0.175	0.300	0.260	0.293	0.066	0.073	0.187
P3,4	0.300	0.300	0.291	0.297	0.228	0.300	0.203
P4,1	0.002	0.001	0.001	0.011	0.076	0.110	0.001
P4,2	0.003	0.001	0.005	0.005	0.112	0.004	0.195
P4,3	0.0005	0.001	0.000587	0.000587	0.052	0.300	0.178
P4,4	0.001	0.001	0.002	0.002	0.140	0.013	0.198
PT1,2	NA	NA	NA	NA	-0.032	0.001	0.060
PT1,3	NA	NA	NA	NA	-0.009	0.001	0.040
PT1,4	NA	NA	NA	NA	0.170	0.128	0.126
PT2,3	NA	NA	NA	NA	-0.032	0.001	0.035
PT2,4	NA	NA	NA	NA	0.052	0.001	0.055
PT3,4	NA	NA	NA	NA	0.005	0.001	0.009
Transmission Cost (TC)	NA	NA	NA	NA	NA	NA	0.146
Power Losses (P_L)	NA	NA	NA	NA	NA	NA	0.00004
Total Fuel Cost	2002.350	1984.300	1998.640	1995.80	2166.82	2126.927	1883.097
Total Operating Cost (TOC)	NA	NA	NA	NA	NA	NA	1883.244
Total Emissions	0.066	0.087	0.070	0.072	3.315	NA	0.066
CEED	NA	NA	NA	NA	NA	NA	1919.780

NA – Not available in cited literature.

The results obtained collectively for cases 1, 2 and 3 are shown in Table 2. P(i) represents the power purchased to area 1 and P(o) represents the power available for sale from area 2. It is concluded from the results obtained that the purchase of power at 150 $/MW reduces the total fuel cost from 1883.097 $/hr. to 1875.692 $/hr. in case 2 and to 1856. $/hr. in case 3. Also, the emissions reduced from 65.878 Kg/hr. to 56.408 Kg/hr. in case 2 and to 65.146 Kg/hr in case 3. Thus, it is economical to purchase power from external source, which also be beneficial in reducing the overall emissions from the areas considered.

Fig. 1 shows the power transfer on the tie lines for cases 1, 2 and 3.This power transfer satisfies the overall power demand constraint, such that the total power generated in the whole region must be equal to the total power demand, power transfer on tie lines and transmission losses.

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From Table 2 and 3, it is observed that the power purchased from external source be at lower incremental cost.

Table II. Comparison of Results Obtained from Different Cases Considered

Unit Power Output (P.U.)	**Case 1**	**Case 2**	**Case3**
P1,1	0.085	0.023	0.023
P1,2	0.100	0.100	0.100
P1,3	0.130	0.130	0.130
P1,4	0.120	0.120	0.120
P2,1	0.037	0.091	0.040
P2,2	0.120	0.120	0.120
P2,3	0.193	0.191	0.192
P2,4	0.180	0.180	0.180
P3,1	0.001	0.001	0.001
P3,2	0.189	0.186	0.187
P3,3	0.187	0.185	0.186
P3,4	0.203	0.200	0.201
P4,1	0.001	0.001	0.001
P4,2	0.195	0.193	0.194
P4,3	0.178	0.176	0.176
P4,4	0.198	0.196	0.197
Total Power	2.115	2.092	2.048
PT1,2	0.060	0.049	0.053
PT1,3	0.040	0.040	0.037
PT1,4	0.126	0.124	0.124
PT2,3	0.035	0.034	0.033
PT2,4	0.055	0.047	0.052
PT3,4	0.009	0.009	0.008
Transmission cost (TC)	0.146	0.198	0.117
Power Losses (P_L)	0.000038	0.000037	0.000036
Total Fuel Cost	1883.097	1875.692	1856.497
Total Operating Cost (TOC)	1883.244	1875.890	1856.614
Total Emissions	65.878	56.408	65.146
CEED	1919.780	2132.435	2197.789
P(i)	0	0.05	0.05
P(o)	0	0.05	0

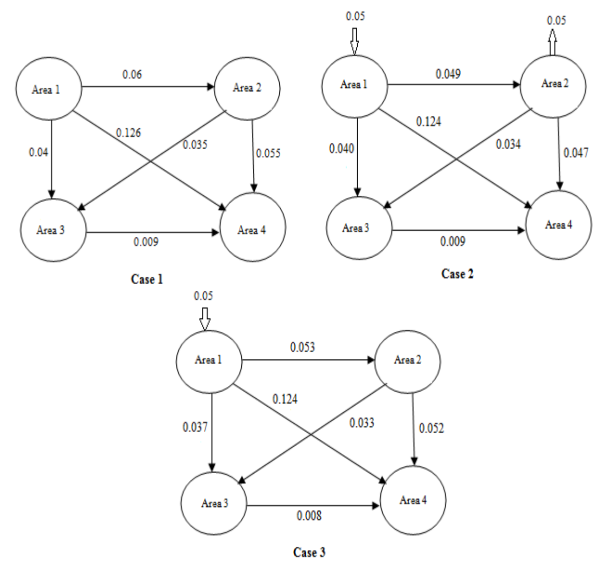

Fig. 1. Power Flow on Tie Lines in Different Cases Considered

Table III. Results Obtained Under Different Areas

Cases	**Area 1**	**Area 2**	**Area 3**	**Area 4**
1 (Pi,j)	0.435	0.53	0.579	0.571
2 (Pi,j)	0.373	0.582	0.573	0.564
3 (Pi,j)	0.373	0.532	0.576	0.567
P(i)	0.050	0.05	0	0
P(o)	0.000	0.05	0	0
Incremental	345.620	541.332	605.077	728.054
Total Fuel	359.296	517.476	487.296	511.625

Hence this becomes beneficial for the region under testing to purchase that power and reduce its overall fuel cost. Table 3 also shows the power produced by each area and its corresponding incremental cost and fuel cost.

V. CONCLUSION

This paper presents a modified novel approach for solving the dispatch of multiarea system. The proposed algorithm includes the hybridization of particle swarm optimization (PSO) with simplex search method (SM). It is done to overcome some limitations of PSO like premature convergence and stagnation in the solution. In the proposed algorithm, PSO is used as a base level search and further, SM is used as local level search to improve the solutions received from PSO and to reach the global optimum solution. The dispatch problem consists of minimization of fuel cost and pollutants' emission from the multiarea system, which give rise to multiobjective problem. Due to the conflicting nature of reducing fuel cost and emission simultaneously, price penalty factor is used to convert the multiobjective problem into single objective. Transmission losses are also included to have the practical impact in the problem. A test system consisting of four areas having four generators in each area connected with six tie lines is considered. Other cases including the purchase from external sources and sale to external sources is also taken into account, from where it is concluded that total fuel cost and emissions are reduced when power is purchased at lower incremental cost. The comparison of the results obtained from the proposed algorithm is done with other papers cited in the literature and overall improved results are observed.

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