Space Reduction Strategy based Particle Swarm Optimization Technique for the Solution of Environmental/Economic Dispatch Problem

T. Manoj Kumar, N. Albert Singh

Abstract--- ***Proposed for the ideal arrangement of eco-friendly economic power dispatch problem of thermal units, an expert release of particle swarm optimization technique is presented in this paper. A space reduction strategy based PSO is analyzed here to solve the EED problem to acquire the Pareto ideal arrangement in the recommended pursuit space by upgrading the speed of optimization process. PSO is one of the nature based algorithm enlivened by the sociological behavior which can be utilized in variety of engineering applications. So many papers are available nowadays for the proper analysis and some of the papers are utilized for literature review. Search space reduction strategy can be applied to our existing particle swarm optimization to increase the speed of moving particles in order to attain Pareto optimal global solution. Here the validation of SR-PSO is demonstrated with an Indian test system with 6 generators. Our main aim is to dispatch the system with minimum operating fuel cost with least emission.***

Keywords--- ***Environmental/Economic Dispatch problem, Pareto Optimal solution, Search Space Reduction Particle Swarm optimization.***

I. INTRODUCTION

The critical target of economical division (ED) of electric power system is to plan the submitted producing unit yields in order to take care of the required load demand at least working expense while fulfilling all unit and framework uniformity and imbalance constrictions. Normally power dispatches have been conducted in thermal fuelled plants to get least fuel cost without bearing in mind the contamination delivered. The most basic crisis in the organizing and action of electric power framework structure is the practical booking of all generators in a system to deal with the required load request. Anyway the perfect prudent dispatch may not be the best similar to the characteristic criteria. These days various countries through the world have concentrated on the decline of the proportion of toxins from oil subsidiary power creating units. The two basic power plant releases from a dispatching perspective are Sulfur oxides (SO2) and nitrogen oxides (NOx).The financial dispatch and discharge dispatch are impressively unique. The economic dispatch diminishes the aggregate fuel rate (working expense) of the framework at an expanded rate of contamination. Then again emission dispatch diminishes the aggregate discharge from the framework by an expansion in the power system working expense. Along these lines it is imperative to find out employed point that strikes an agreement among expense and emanation. This is accomplished by combined economic and emission dispatch problem (EED).

The Collective Environmental Monetary Dispatch (EED) problem is a bi criteria optimization problem with two clashing target capacities: total fuel rate and total emanation. Because of the clashing destinations and non-commensurable natures of fuel rate and outflow minimization objectives, customary procedure which upgrades the planned two target limits shows up not fitting for this class of multi-target improvement issues. Hence, traditional optimization techniques based on derivatives and gradients are not appropriate for this nonlinear and multimodal problem. Distinctive methods have been accounted for in the writing relating to ecological/financial dispatch (EED) issue. In[1], a linear programming design method is analyzed for the solution of multi-objective problem was explained. A dynamic monetary dispatch utilizing broadened security limitation financial dispatch arrangement was clarified in [2]. In [3] zoom highlight of dynamic programming answer for financial dispatch technique is illustrated. In [4] and [5], dynamic economic dispatch and non-linear programming technique by considering the problem as single objective function was given. In [6] the valve point effects are considered and in [7] quadratic programming method for the solution of EED solution. A semi static financial dispatch utilizing dynamic programming with enhanced zoom include was given in [8].In [9] economic load dispatch problem with line flow constraints using the classical technique was modeled. A blended whole number quadratic programming detailing was clarified in [10].

The essential objective on this examination ought to be to introduce the usage of SRPSO optimization technique to the theme of economic post in power systems. In order to handle the complexity and non-linearity with the EED problem, a space reduction strategy based on SR-PSO is used.SR-PSO is considered as a derivative free algorithm, in no way like the ordinary optimization algorithms so it is employed as a part of dealing with environmental economical dispatch problem. SRPSO has a adaptable and well balanced mechanism to improve exploration and exploitation talents. Here, the SRPSO scheme has become

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recommended to resolve environmental economic dispatch problems for the evaluation of given Indian Test system having 6 units.

The computing time of common strategies is excessive as well as the classic strategies just fuel price. So this paper is usually offered to ascertain sensible environmental/ economic dispatch concerns (EED) utilizing SR-PSO. This work is divided into four sections: Section 2 formulates the EED problem with limitation conditions. Section 3 brands the rendering of offered SR-PSO in EED difficulty. Finally the Division 4 precise the paper and offers some recommendation for foreseeable future research. The various results with the proposed SR-PSO technique were analyzed and through a comparative study, those results were compared with that results which were reported in literature review papers.

II. PROBLEM ORIGINATION

The primary target of EED issue is to limit our fundamental target capacities, for example, cost capacity and discharge works by satisfying the current working limitations. These imperatives can be fairness and disparity limitations. Normally the issue is planned as given underneath.

1) Reduction of fuel rate

For N number of generators are under consideration, total fuel rate can be formulates as follows

$$F(p_g) = \sum_{i=0}^{N} F_i\,(P_i) = \sum_{i=1}^{N} a_i P_i^2 + b_i P_i + c_i \quad (1)$$

Where $F(p_g)$-denotesthe total generation fuel cost

P_i-represents the electrical production of i^{th} unit

a_i, b_i and $c_i$signifies the rate factors of i^{th} unit

N-denotes the quantity of producers assigned to the operating system

2) Reduction of emanation

The entire emission with the fossil gas based heat generation could be given by,

$$E(P_g) = \sum_{i=1}^{N} E_i\,(P_i) = \sum_{i=1}^{N} (\alpha_i\,P_i^2 + \beta_i P_i + \gamma_i \quad (2)$$

$\alpha_i, \beta_i, \gamma_i$are the emission coefficients of i^{th} unit.

Multi-objective search engine optimization problem offers two goals which are overall economy and emission. It is transformed in to solitary objective search engine optimization problem as,

$$T(P_g) = \alpha * F(P_g) + (1-\alpha)E(P_g) \quad (3)$$

Where $T(P_g)$ is definitely total cost and 0< α<1 is a compromise factor. In the point when α is zero, which denotes the pollutant division. At the stage when α is 1, the impartialtask becomes complete conventional economical burden dispatch problem which restricts aggregate the availability expenses of this scheme.

3) Problem constraints

a) Constrictions of generator units

The genuine power efficiency of each generator will be amidst its base and ideal cutoff points and the disparity imperatives implied for each generator should be guaranteed.

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max}, \quad \text{i=1.......N} \quad (4)$$

$P_{gi}^{min}$and P_{gi}^{max} are the inferior and superior boundaries of i^{th} power units simultaneously.

b) Power balance constrictions

The aggregate power loss has the real power reduction in transmission line P_L and total demand P_D. Then,

$$\sum_{i=1}^{N} P_{gi} - P_D - P_L = 0 \quad (5)$$

In which the system loss function P_L is given by,

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} (P_i\,B_{ij} P_j) MW \quad (6)$$

Where P_D and P_L are MW total load demand and total transmission losses in MW respectively.By considering the clashing two target capacities (3), (4) and the two imperatives (5), (6), the EED issue can be numerically defined as pursues:

Minimisation of $[F(p_g), E(P_g)]$

Subject to constraints g(p_g) = 0 and h(p_g) ≤ 0

Where g(p_g) speaks to fairness requirement speaking to the power balance condition and h(p_g) is the imbalance limitation speaking to the unit age limit condition. Commonly environmental/economic dispatch problem can be formulated either one of the two main functions are to be treated as main objective function and other as constraint. If fuel rate is the main objective and emanation as constraint then overall system becomes emissions constrained economic dispatch (ECED). If both functions are considered to be minimized then overall problem becomes multi-objective optimization problem (EED). This can be achieved by the use of weighted sum approach to correlate total fuel rate and total emanation.

$$\text{Minimise: } \alpha \sum_{i=1}^{N} F(\mathrm{P_g}) + (1-\alpha) \sum_{i=1}^{N} E(P_g)$$

$$\text{Subjected to : } \sum_{i=1}^{N} P_i = P_D + P_L$$

$$P_i^{\min} \le P_i \le P_i^{\max} \;,\; i = 1,2........N \quad (7)$$

III. IMPLEMENTATION OF SR-PSO IN EED PROBLEM

PSO is a population based self-adaptive stochastic contemporary heuristic global search algorithm.It is comprehensively used for the goals of intensely constrained dispatch issue. The procedure in PSO begins with the period of set number of discretionarily produced particles (potential arrangements) dispersed inside a multi-dimensional arrangement space. The fowls (particles) move all through the multi-dimensional pursuit space (where the arrangement really exists) till they find the sustenance (ideal arrangement). The molecule inside the swarm clarifies a hopeful quality and strategies towards the best point by the speed utilizing its position. These positions and speed are given by specific conditions.The best position of each particle can be found in search space by recording for each step of velocity and position. So the optimal solution is obtained as these particles move inside the multi-dimensional space.

By own knowledge (P^{best}) and the knowledge achieved by nearest particles (G^{best}) every particle "updates a situation throughout the flight. Thus each particle utilizes P^{best} and G^{best} . The fitness function calculation at (k+1) iteration for all particles, the speed and position of i^{th} particle are calculated shown by following equations,

$$V_i^{k+1} = W.V_i^k + C_1.r_1.(Pbest_i - x_i^k) + C_2.r_2.(Gbest_g - x_i^k) \quad (8)$$

$$P_i^{k+1} = P_i^k + V_i^{k+1}, \quad V_i^{k=0} = 0 \qquad (9)$$

where, i- symbolizes each particles turn, k- represents the digital-time index, m and n represents total numbers in a group and dimension of space respectively. W symbolizes inertia compromise factor, P^{best} , G^{best} denotes best position acquired by the i^{th} particle's and the best position attained by flock respectively. C_1, $C_2 -$ Symbolizes the acceleration coefficients, $r_1, r_2 -$ Represents a constant value which varies from zero to one. $P_i^k, V_{i,}^k -$ Indicate the location and swiftness of i^{th} element at k^{th} repetition.

Here we can introduce a new technique in order to reduce the search space using search space reduction strategy with existing particle swarm optimization method. This method can be activated when the performance isn't increased throughout a pre-specified time.This can be achieved by introducing a constant Δ in order to regulate the existing search space. The revised values of position can be obtained as follows.

$$P_{i\max}^{k+1} = P_{i\max}^{k} - (P_{i\max}^{k} - Gbest_i^k)\Delta$$

$$P_{i\min}^{k+1} = P_{i\min}^{k} + (P_{i\min}^{k} - Gbest_i^k)\Delta$$

The update of inertia weight is essential during iteration process. This has to be done according to cycles. The up gradation of inertia weight is give below.

$$w = \exp\left(-\eta log_e\left(\frac{W_{max}}{W_{min}}\right)\right); \eta = \frac{itr}{itr_{max}} \ldots\ldots\ldots(10)$$

Using the weighted sum method, both the objectives can be joined together into one multi-objective function by the proper usage of one weighing factor which is known as compromise factor. So the environmental economic dispatch can be represented as follows.

$$F_t = \alpha * Fcost_i + (1-\alpha) * Ecost_i \ (11)$$

The above equation is formed using the compromise factor αwhich decides the nature of dispatch that is either economic dispatch or emission dispatch. The value of this compromise factorhave to be varied from 0 to 1 and when this value is 0.5 there is a chance of getting minimum total fuel rate and minimum pollutant.

3.1 Algorithm and flow chart for SR-PSO Method

The formulation of EED problem using SR-PSO is given as follows,

Step 1: Initialization

- Form the multi-objective function using cost and emission coefficients.
- Set the initial velocity as zero
- Initialize the position of particles randomly

Step 2: Position upgrade

- For every particle upgrade the position and velocity.
- Using the given constraints update each particle's position and velocity.

Step 3: Determine the fitness function values of all particles.

Step 4: Evaluate P^{best} , G^{best} using the equations and save the corresponding positions.

Step 5: Apply space reduction strategy based PSO algorithm.

Step 6: Go to step 2 till the required criterion is obtained.

The flowchart of proposed PSO method is shown on Figure 1. Using the following equations update the position and velocity of i^{th} particle can be calculated.

$$v(k+1) = W * V(k) + (C_1 * rand1 * (p_i - x(k)) + (C_2 * rand2 * (P_b - x(k))..(12)$$

$$x(k+1) = x(k) + v(k+1) \ (13)$$

$$C_1 = ((C_{1f} - C_{1i}) * {}^{iter}/_{iter_{max}} + C_{1i}) \quad (14)$$

$$C_2 = ((C_{2f} - C_{2i}) * {}^{iter}/_{iter_{max}} + C_{2i}) \ (15)$$

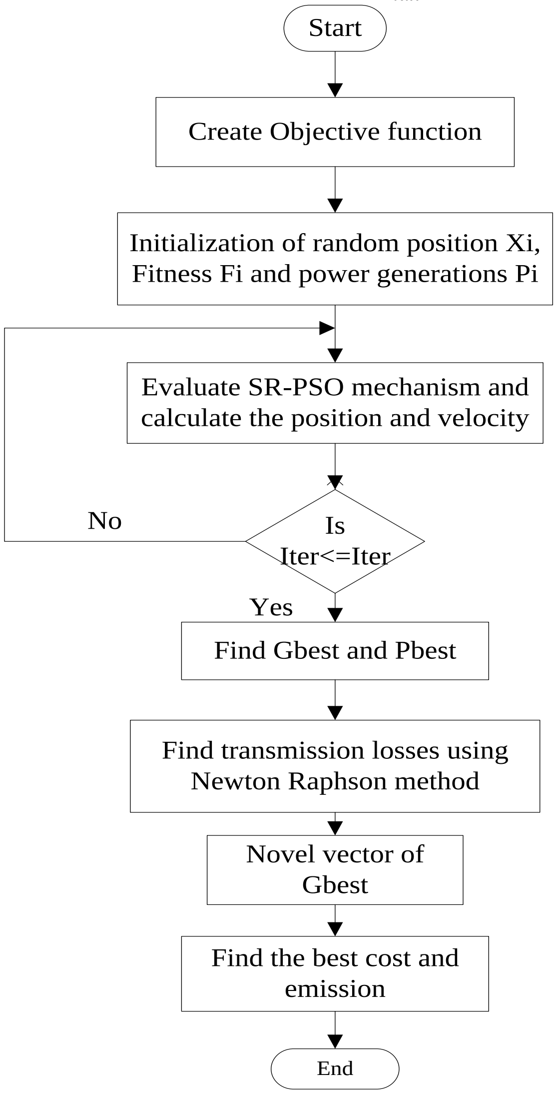

Figure 1: Flowchart for proposed EED problem based on SR-PSO

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IV. SIMULATION RESULTS AND ANALYSIS OF PERFORMANCE

Test System: Indian Utility System

The proposed SR-PSO method is examined utilizing Indian utility system with six generators. The fuel cost

α	Thermal unit No. P_{G1}	P_{G2}	P_{G3}	P_{G4}	P_{G5}	P_{G6}	Total Fuel Rate ($/hr)	Total Pollutant(kg/hr)	Transmission Loss (MW)
1.0	36.8322	21.0502	163.904	153.225	284.125	272.855	47044.5894	821.9842	31.9911

constants, emission constants, lower and upper constraints and transmission loss coefficient matrix B_{ij} are shown in Table 1 and Table 2.

Here only NO_x emission is considered for optimization of the multi-objectiveproblem. The simulation of SRPSO isdone for a power demand of 900MWusing the MATLAB programming environment.The enhancement results with various alpha values with the step of 0.1 are generatedin Table 3.

The perfect arrangement of economic and emission dispatch results for SRPSO is illustrated and is compared with [11] which are given in Table 5. The variation of total fuel rate with total pollutant is illustrated in Figure 2 for different values of alpha. The best negotiationresult can be obtained from the resultant chart.

Table 1: Fuel cost and emission coefficients of Indian Utility System

plant	unit	a	b	c	d	e	f	P_{min}	P_{max}
1	G1	0.15247	38.53973	756.79886	0.00419	0.32767	13.85932	10	125
	G2	0.10587	46.15916	451.32513	0.00419	0.32767	13.85932	10	150
	G3	0.02803	40.39655	1049.32513	0.00683	-0.54551	40.2669	40	250
2	G4	0.03546	38.30553	1243.5311	0.00683	-0.54551	40.2669	35	210
	G5	0.02111	36.32782	1658.5696	0.00461	-0.51116	42.89553	130	325
3	G6	0.01799	38.27041	1356.65920	0.00461	-0.51116	42.89553	125	315

Table 2: Transmission Loss coefficients of Indian Utility System

$$B_{ij} = \begin{bmatrix} 0.00014 & 0.000017 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \\ 0.000017 & 0.00006 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000015 & 0.000013 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000019 & 0.000016 & 0.000017 & 0.000071 & 0.000030 & 0.000025 \\ 0.000026 & 0.000015 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000022 & 0.000020 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \end{bmatrix}$$

Table 3: Optimization Results of Indian Utility System

α	Thermal unit No. P_{G1}	P_{G2}	P_{G3}	P_{G4}	P_{G5}	P_{G6}	Total Fuel Rate ($/hr)	Total Pollutant(kg/hr)	Transmission Loss (MW)
1.0	36.8322	21.0502	163.904	153.225	284.125	272.855	47044.5894	821.9842	31.9911
0.9	37.2743	21.7438	164.053	153.523	283.351	271.987	47044.6974	820.0520	31.9316
0.8	37.7609	22.5112	164.111	153.984	282.296	271.205	47045.1182	817.7176	31.8675
0.7	38.3969	23.6189	164.354	154.342	280.932	270.135	47046.1106	814.8329	31.7789
0.6	39.2135	24.8197	164.715	154.972	279.163	268.789	47048.1127	811.2078	31.6724
0.5	40.2863	26.8122	164.877	155.454	276.821	267.280	47052.1606	806.3543	31.5296
0.4	41.9810	29.4830	164.947	156.156	274.323	264.443	47060.3898	799.7508	31.3326
0.3	44.4765	33.5166	164.965	157.043	270.040	261.012	47078.8459	790.2503	31.0520
0.2	48.8784	40.7599	165.073	157.820	263.109	254.938	47128.0946	774.4303	30.5787
0.1	59.8553	57.3184	161.736	157.262	249.940	243.570	47316.9244	743.2557	29.6819
0.0	120.7601	125.157	140.348	139.118	201.299	200.691	49650.0760	682.6287	27.3731

Table 4: Simulation Results of Indian Utility System

Test system	Control variables	SR-PSO P_L(MW)	SR-PSO Total fuel rate($/hr)	SR-PSO Total Pollutant(kg/hr)
Indian Utility system	P_D=900MW, α=0	27.3731	49650.0760	682.6287
	P_D=900MW, α=0.5	31.5296	47052.1606	806.3543
	P_D=900MW, α=1	31.9911	47044.5894	821.9842

Table 5: EED results with demand of 900MW

Parameters	SR-PSO		[11] Method	
P_{Gi} for unit/ loss (MW)	Economic dispatch (MW)	Emission Dispatch (MW)	Economic dispatch (MW)	Emission Dispatch (MW)
1	36.8322	120.7601	33.77	124.51
2	21.0502	125.1566	12.65	124.51
3	163.9036	140.3481	150.56	140.31
4	153.2245	139.1177	148.50	140.31
5	284.1253	201.2994	296.29	204.15
6	272.8553	200.6911	293.68	204.15
P_L(MW)	31.9911	27.3731	35.44	37.90
Cost ($/hr)	47044.5894	49650.076	47187.41	50217.56
Emission(kg/hr)	821.9842	682.6287	857.74	696.92

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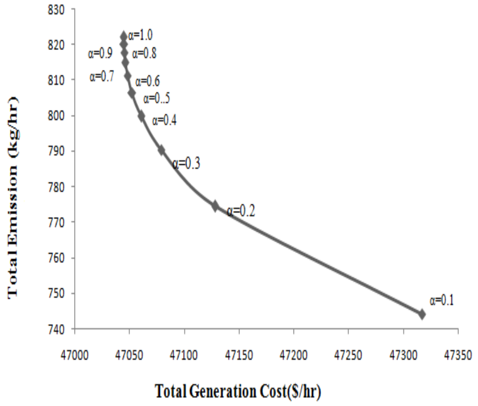

Figure 2: Variation of generation cost with emission for different values of α

V. CONCLUSIONS

A space reduction strategy based particle swarm optimization algorithm is proposed here to find the optimal resolution of environmental/economic power dispatch issue. The dispatch problem is conducted into multi-objective optimization with total fuel rate and total pollutants are the basic objectives in order to reduce concurrently. These two goals are combined in to a solitary target by using the weighted total strategy. Best expense and best discharge goals are achieved for a specific stacking condition for Indian utility system with six generators. All the chose requirements are fulfilled amid the recreation procedure. It is seen from the correlation that the proposed methodology gives an aggressive execution in states of goals and also calculation time. The proposed SRPSO is robust, productive and simple.

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