ECONOMIC EMISSION DISPATCH SOLUTION USING PARALLEL SYNCHRONOUS PSO ALGORITHMS

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ABSTRACT

This paper presents recent advances in applying parallel synchronous PSO algorithms for Optimal Power Flow in Combined Economic Emission Dispatch environment of thermal units while satisfying the constraints such as generator capacity limits, power balance and line flow limits. The use of orthogonal polynomials will give a very convenient means to obtain the equivalent cost function of the generating units. A general formulation and the development of Cascade Correlation algorithm to solve the environmentally constrained dispatch problem are presented. The objective is the minimization of the cost of operation, subject to all the usual and emissions constraints. The results obtained by the proposed method are better than any other evolutionary computation techniques proposed so far.

Keywords: *Economic dispatch, Emission dispatch, Load Flow, parallel synchronous PSO algorithms, Particle Swarm Optimization*

1. INTRODUCTION

Economic load dispatch is one of the main functions of electrical power management systems. The main objective of economic load dispatch is to minimize the fuel cost while satisfying the required equality and inequality constraints. One of those constraints which is always taken into account is the environmental constraint. That is minimization of pollution emission (NOx, CO2, SO2, small quantities of toxic metals, etc) in case of power plants [2]. Recently, a global parallel synchronous PSO algorithm which is a kind of the probabilistic heuristic algorithm has been studied to solve the power optimization problems. The (PS-PSO) may find several sub-optimum solutions within a realistic computation time. Even if there is no guaranty that the PS-PSO may find the global optimal solutions in a finite time. The paper presents a methodology to overcome long computation times by applying simple Parallel Synchronous Particle Swarm Algorithms. The fast computation feature of the developed algorithm is advantageous and can be used in on line power system studies.

2. PROBLEM FORMULATION

The Economic Load Dispatch (ELD) and Emission Dispatch (ED) are solved separately. Suitable generating power units are leaved the total demand power after making the ELD and ED. According to the rest of total power demand, ELD and ED are made solution. When the total power demand and required constraints are suitable for all power system, EED is done. The total fuel cost and emission are calculated together in EED step [11]. When the convergence is done the problem will be solved. There is a convergence whenever the cost circumstances are changed, such as it increases or decreases.

Then, generating unit's powers are saved. EED problem is composed of mainly two types of objective functions, ELD and ED subject to equality and inequality constraints. Each problem is detailed as follows:

2.1. Economic Load Dispatch

ELD problem is to find the optimal combination of power generation that minimizes the total fuel cost while satisfying the total demand and power system constraints. The fuel costs for power generation units should be defined. The total fuel cost function of ELD problem is defined as follows [1]:

$$\mathrm{Min}\left[\sum_{i=1}^{n} F(P_i)\right] = \mathrm{Min}\left[\sum_{i=1}^{n}(a_i P_i^2 + b_i P_i + c_i)\right] \tag{1}$$

where
P_i is: the power output of i-th generator in MW;
$F(P_i)$: is the total fuel cost of electrical power generation in \$/h;
a_i, b_i, c_i : are the cost coefficients of the i-th generator.

2.2. Emission Dispatch

The aim of ED problem is to minimize total emission of all thermal units. The amount of emission from a fossil-based thermal generator unit depends on the amount of power generated by the unit. Total emission generated also can be approximated as sum of a quadratic function and an exponential function of the active power output of the generators. The emission dispatch problem can be described as the optimization of total amount of emission release defined by as [12]:

$$\begin{aligned}\mathrm{Min}[Emi] &= \mathrm{Min}\left[\sum_{i=1}^{n} E(P_i)\right] \\ &= \mathrm{Min}\left[\sum_{i=1}^{n}(\alpha_i P_i^2 + \beta_i P_i + \lambda_i)\right]\end{aligned} \tag{2}$$

where
$E(P_i)$: Total emission release in Kg/hr;

α_i, β_i and λ_i : are the emission function coefficients of the i-th generating unit.

2.3. Economic Emission Dispatch

An aggregating equation (1) to (2), the power dispatch problem is expressed as a bi-objective optimization problem as follows [12]:

$$\begin{aligned} Cost &= Min\left[\sum_{i=1}^{n} F(P_i), Emi\right] \\ &= Min\left[\sum_{i=1}^{n} F(P_i)\right] + Pf_i * Min[Emi] \end{aligned} \tag{3}$$

where

Pf_i : is the price penalty factor.

The ratio between the average fuel cost and the average emission for maximum power capacity of that plant is found:

$$Pf_i = \frac{F(P_i^{max})}{E(P_i^{max})} \tag{4}$$

Equality constraints: Generation-demand balance as an equality constraint [2]:

$$\sum_{i=1}^{n} P_i - P_D - P_L = 0 \tag{5}$$

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} B_{ij} P_i P_j \tag{6}$$

where

P_D : Total demand (MW);

P_L : Transmission losses (MW);

B_{ij} : are the elements of loss coefficient matrix technique.

D. Inequality Constraints: Generation power should be within the minimum output P_{i-min} and the maximum output P_{i-max}.

$$P_{i-min} \le P_i \le P_{i-max} \tag{7}$$

3. PARALLEL SYNCHRONOUS PARTICLE SWARM OPTIMIZATION

Parallel synchronous optimization algorithms work best when three conditions are met. First, the optimization has total and undivided access to a homogeneous cluster of computers without interruptions from other users. Second, the analysis function takes a constant amount of time to evaluate any set of design variables throughout the optimization. Third, the number of parallel tasks can be equally distributed among the available processors. If any of these three conditions is not met, the parallel optimization algorithm will not make the most efficient use of the available computational resources [13].

Particle Swarm Optimization (PSO) was first proposed by Kennedy and Eberhart in 1995. This technique was inspired from the choreography of a bird flock and can be seen as a distributed behavior algorithm that performs multidimensional search. According to PSO, the behavior of each individual is affected by either the best local or the best global individual to help it fly through a hyperspace. Moreover, an individual can learn from its past experiences to adjust its flying speed and direction. Therefore, by observing the behavior of the flock and memorizing their flying histories, all the individuals in the swarm can quickly converge to near-optimal geographical positions with well-preserved population density distribution [13].

In a PSO system, a swarm of individuals (called particles) fly through the search space. Each particle represents a candidate solution to the optimization problem. The position of a particle is influenced by the best position visited by itself (own experience) and the position of the best particle in its neighborhood (the experience of neighboring particles). When the neighborhood of a particle is the entire swarm, the best position in the neighborhood is referred to as the global best particle, and the resulting algorithm is referred to as a Gbest PSO. When smaller neighborhoods are used, the algorithm is generally referred to as a lbest PSO. The performance of each particle is measured using a fitness function that varies depending on the optimization problem [14].

While several modifications to the original PSO algorithm have been made to increase robustness and computational throughput, one of the key issues is whether a synchronous or asynchronous approach is used to update particle positions and velocities. The sequential synchronous PSO algorithm updates all particle velocities and positions at the end of every optimization iteration [13].

Each particle i is represented as a D-dimensional position vector $\vec{x_i}(t)$ and has a corresponding instantaneous velocity vector $\vec{v_i}(t)$. Furthermore, it remembers its individual best value of fitness function and position $\vec{x_L}$ which has resulted in that value. During each iteration t, the velocity update rule is applied on each particle in the swarm. The $\vec{x_g}$ is the best position of the entire swarm and represents the social knowledge [4].

$$\begin{aligned} \vec{v_i}(t) = \omega.\vec{v_i}(t-1) + \varphi_1.R_1.(\vec{x_L} - \vec{x_i}(t-1)) \\ + \varphi_2.R_2.(\vec{x_g} - \vec{x_i}(t-1)) \end{aligned} \tag{8}$$

$$\omega = \omega_{end} - \left|\frac{\omega_{end} - \omega_{start}}{iter_{max}}\right|.iter \tag{9}$$

where

ω : called inertia weight and during all iterations decreases linearly from ω_{start} to ω_{end} ;

R_1 and R_2 : The diagonal matrices with random diagonal elements drawn from a uniform distribution between 0 and 1;

φ_1 and φ_2 : are scalar constants that weight influence of particles' own experience and the social knowledge.

Next, the position update rule is applied:

$$\vec{x}_i(t) = \vec{x}_i(t-1) + \vec{v}_i(t) \tag{10}$$

The PSO updates the particles in the swarm using equations (6) and (7). This process is repeated until a specified number of iterations are exceeded, or velocity updates are close to zero. The quality of particles is measured using a fitness function which reflects the optimality of a particular solution.

4. ALGORITHM

The algorithm for solving the combined emission and economic dispatch problem using Parallel Synchronous PSO method is given below:

For each particle I = 1:to m **Do**
Randomly initialize $P_G(i)$ $\quad \{\boldsymbol{P_{min}} < \boldsymbol{P} < \boldsymbol{P_{max}}\}$
Randomly initialize v(i)
Initialized $P_{G-self}(i) = P(i)$
End-For
Repeat
For each particle I = 1:to m **Do**
Compute transmission losses using

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} B_{ij}P_iP_j$$

Compute $\Delta P = \sum_{i=1}^{n} P(i) - P_D - P_L$

Check $|\Delta P| \geq \omega$

IF yes then do

Modify $P(i) = P(i) + \dfrac{P^{max}(i) - P(i)}{P^{max}(i) - P(i)} * \Delta P$

End-IF

Compute

$$\sum_{G1}^{n} F(P_G(i)) = \sum_{i=1}^{n} (a_{Gi}P_G(i)^2 + b_{Gi}P_G(i) + c_{Gi})$$

Compute

$$Emi(i) = \sum_{iG}^{n} E(P_G(i)) = \sum_{i=1}^{n} (\alpha_{Gi}P_G(i)^2 + \beta_{Gi}P_G(i) + \lambda_{Gi})$$

Compute

$$Cost(P_G(i)) = \sum_{G1}^{n} F(P_G(i)) + PF_i * Emi(i)$$

Compare $Cost(P_G(i))$

with: $\begin{cases} Cost(P_{G-self}(i)) & \text{own experience} \\ Cost(P_{G-best}) & \text{global experience} \end{cases}$

End-For

For each particle I = 1:to m **Do**

Update $\begin{aligned} v(i) &= \omega.v(i) + \varphi_1.R_1.(P_{G-self}(i) \\ &- P_G(i)) + \varphi_2.R_2.(P_{G-best} + P_G(i)) \end{aligned}$

Update $P_G(i) = P_G(i) + v(i)$

End-For

Until some convergence criteria is satisfied.

5. SIMULATION RESULTS

The proposed approach is tested on the IEEE 30-bus system [4].

The fuel cost equations in \$/h for the three generators are:

$$F_1(P_1) = 0.03546 * P_1^2 + 38.30553 * P_1 + 1243.5311$$
$$F_2(P_2) = 0.02111 * P_2^2 + 36.32782 * P_2 + 165.5696$$
$$F_3(P_3) = 0.01799 * P_3^2 + 38.27041 * P_3 + 1356.6592$$

The emission equations in kg/h are:

$$E_1(P_1) = 0.00683 * P_1^2 - 0.54551 * P_1 + 40.2669$$
$$E_2(P_2) = 0.00461 * P_2^2 - 0.51160 * P_2 + 42.89553$$
$$E_3(P_3) = 0.00461 * P_3^2 - 0.51160 * P_3 + 42.89553$$

Power generation limits:

$$35 \leq P_1 \leq 210$$
$$130 \leq P_2 \leq 325$$
$$125 \leq P_3 \leq 315$$

The loss coefficient matrix is:

$$B = 10^{-5} * \begin{bmatrix} 7.1 & 3.0 & 2.5 \\ 3.0 & 6.9 & 3.2 \\ 2.5 & 3.2 & 8.0 \end{bmatrix}$$

The proposed Parallel Synchronous PSO methods have been successfully employed and the results were obtained for IEEE 30-bus system using MATLAB software.

Table 1 Results of optimization process (synchronous PSO)

PD(MW)	400	550	700
P_1(MW)	102.385	142.390	182.457
P_2(MW)	154.014	212.116	271.368
P_3(MW)	151.010	209.707	269.542
P_L(MW)	7.412	14.214	23.368
P_f (\$/h)	44.8	44.8	44.8
$\sum F_G$ (\$/h)	20837.605	27904.350	35463.663
Emi_G (Kg/h)	200.230	381.210	651.585
Cost (\$/h)	29807.917	44982.599	64654.685

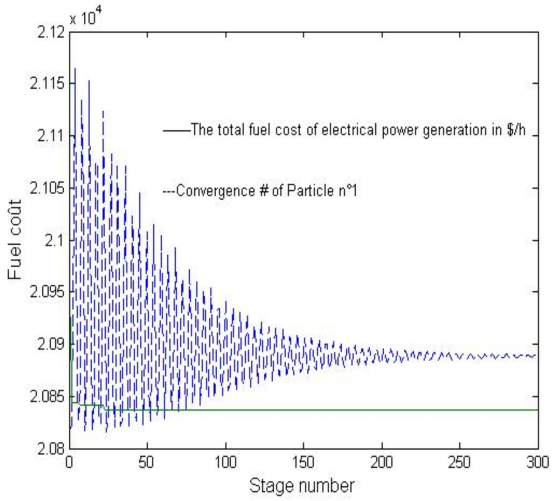

Fig. 1 Total cost for power demand of 400 MW

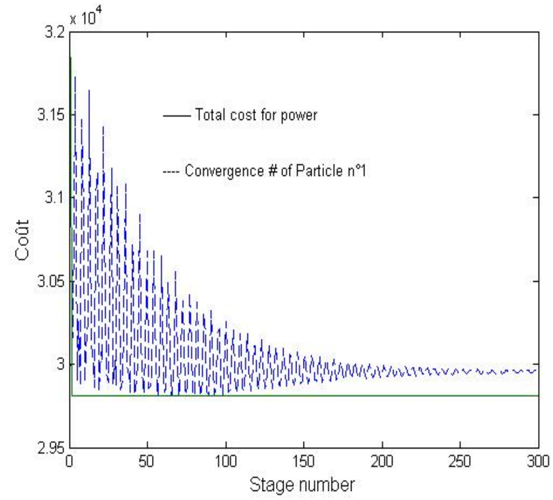

Fig. 2 Fuel cost for power demand of 400 MW

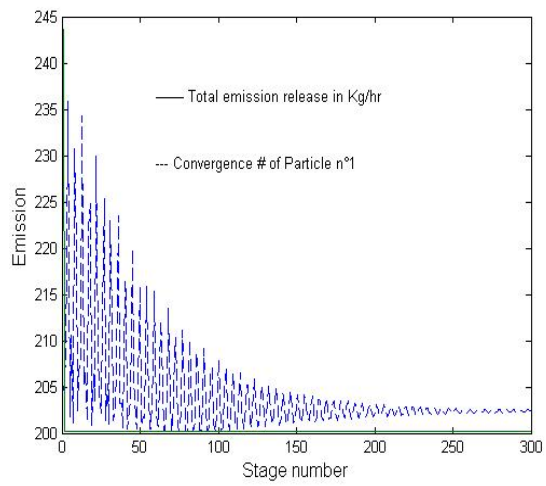

Fig. 3 Emission for power demand of 400 MW

6. CONCLUSION

This paper introduces a new approach based on parallel synchronous PSO algorithms to study the power system Economic Emission dispatch which is formulated as a constrained optimization problem. Incorporating with the proposed constraint handling technique, parallel synchronous PSO algorithms successfully achieved the global optimal solution of the EED problem consisting of 3 generators and were able to obtain the solutions better than the known best solution reported in the literature for the EED problem. Furthermore, the 3 test was conducted to demonstrate that the performance of method is statistically significant.

The better computation efficiency and convergence property of the proposed parallel synchronous PSO algorithms show that it can be applied to a wide range of optimization problems.

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BIOGRAPHIES

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Mohamed Nasri was born on 05.05.1966. In 1988 gradated at Electrical Engineering department of INELEC University a Bomerdes Algeria. Worked for more than 20 years in electrical company. Now prepares a post gradual study in dynamic control domain at university Bechar Algeria.