ECONOMIC EMISSION DISPATCH SOLUTION USING PARALLEL SYNCHRONOUS PSO ALGORITHMS

Abdesselam ABDERRAHMANI, Mohamed NASRI
University of Bechar, B. P. 417 Bechar (08000), Algeria,
e-mail: abderrahmani_a@yahoo.fr, nasri_mohamed08@yahoo.fr

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]:

\[
\text{Min} \left[ \sum_{i=1}^{n} F(P_i) \right] = \text{Min} \left[ \sum_{i=1}^{n} \left( a_i P_i^3 + b_i P_i + c_i \right) \right]
\]

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]:

\[
\text{Min}[\text{Emi}] = \text{Min} \left[ \sum_{i=1}^{n} E(P_i) \right] = \text{Min} \left[ \sum_{i=1}^{n} \left( \alpha_i P_i^2 + \beta_i P_i + \gamma_i \right) \right]
\]

where

- \( E(P_i) \): Total emission release in Kg/hr;
\[ \alpha_i, \beta_i, \lambda_i \]: 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]:

\[
\text{Cost} = \min \left[ \sum_{i=1}^{n} F(P_i, Emi) \right]
\]

\[
= \min \left[ \sum_{i=1}^{n} F(P_i) \right] + P_{f}^{i} * \min [Emi]
\]

where

\[ P_{f}^{i} \]: 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:

\[
P_{f}^{i} = \frac{F(P_{f}^{max})}{E(P_{f}^{max})}
\]

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

\[
\sum_{i=1}^{n} P_i - P_D - P_L = 0
\]

(5)

\[
P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} B_{ij} P_i P_j
\]

(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 \( P_{i-max} \).

\[
P_{i-min} \leq P_i \leq P_{i-max}
\]

(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 \( \vec{x}_1 \) 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].

\[
\vec{v}_i(t) = \omega \vec{v}_i(t-1) + \varphi_1 R_1 (\vec{x}_1 - \vec{x}_i(t-1)) + \varphi_2 R_2 (\vec{x}_g - \vec{x}_i(t-1))
\]

(8)

\[
\omega = \omega_{end} \left[ \frac{\omega_{end} - \omega_{start}}{\iter_{max} - \iter} \right] \iter
\]

(9)

where \( \omega \): called inertia weight and during all iterations decreases linearly from \( \omega_{start} \) to \( \omega_{end} \);

\( R_1 \) and \( R_2 \): The diagonal matrices with random diagonal elements drawn from a uniform distribution between 0 and 1;
€\phi_1$ and $\phi_2$: are scalar constants that weight influence of particles’ own experience and the social knowledge.

Next, the position update rule is applied:

$$x_i(t) = x_i(t-1) + v_i(t)$$  \hspace{1cm} (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 $m$

1. Randomly initialize $P_G(i)$ \{ $P_{\text{min}} < P < P_{\text{max}}$ \}
2. Randomly initialize $v(i)$
3. Initialized $P_{G-self}(i) = P(i)$

End-For

Repeat

For each particle $I = 1$ to $m$

1. Compute transmission losses using
2. Compute $\Delta P = \sum_{i=1}^{n} P(i) - P_D - P_L$
3. Check $|\Delta P| \geq \omega$
4. IF yes then do
5. Modify $P(i) = P(i) + \frac{P_{\text{max}}(i) - P(i)}{P_{\text{max}}(i) - P(i)} \Delta P$
6. End-IF

Compute

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

Compute

$$\text{Emi}(i) = \sum_{G} E(P_G(i)) = \sum_{i=1}^{n} (a_{Gi}P_G(i)^2 + b_{Gi}P_G(i) + c_{Gi})$$

Compute

$$\text{Cost}(P_G(i)) = \sum_{G} F(P_G(i)) + P_F \cdot \text{Emi}(i)$$

Compare $\text{Cost}(P_G(i))$ with: $\text{Cost}(P_{G-self}(i))$ \{ own experience \} and $\text{Cost}(P_{G-best}(i))$ \{ global experience \}

End-For

For each particle $I = 1$ to $m$

1. Update $v(i) = \omega v(i) + \phi_1 R_1 \cdot (P_{G-self}(i) - P_G(i))$
2. 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:

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

The emission equations in kg/h are:

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

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 |
| $\text{Emi}_G$(Kg/h) | 200.230 | 381.210 | 651.585 |
| Cost ($/h) | 29807.917 | 44982.599 | 64654.685 |
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.

REFERENCES


Received September 30, 2010, accepted January 5, 2011

BIographies

Abdesselam Abderrahmani was born on 14.12.1970. In 1994 he graduated at the Electrotechnical Department of the Faculty of Electrical Engineering at University Tiaret in Algeria. He defended his “Magister” In the field of optimal power flow problems in 2008 at university Bechar Algeria; his thesis title was "Optimal design of power system using ant colony". His scientific research is focusing a control and command of power systems, and study of the Dynamic stability of the networks electrical supply.

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.