Journal of Engineering and Applied Science *Volume 4, December 2012*

www.cenresinpub.org
ISSN 2277-0097

AN OPTIMISATION TECHNIQUE FOR REAL AND REACTIVE POWER ALLOCATION

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ABSTRACT

This paper presents a Particle Swarm Optimization (PSO) Technique for Real and Reactive power allocation. In order to optimize the power allocation for a system (power system), a non-linear optimization problem is formulated. The proposed method utilizes the fuel cost coefficient of the generators, transmission losses upper limit and lower limit of the various generating units to optimize power allocation. A Power system with three generating units is considered. Assumed load demands of 200MW is used to compute the power allocation of the 3 generating units as well as the optimized operational cost. The optimized power allocations for the three generating units are obtained by MATLAB scripts on a Matlab 7.5 running on a windows vista operating system.

KEYWORDS: *Particle Swarm Optimization (PSO), Global Best (gbest), Personal Best (pbest), Unit Commitment (UC).*

INTRODUCTION

The optimal system operation, in general, involves the consideration of economy of operation, system security, emission at certain fossil-fuel plants and so on. **[1]** Optimization entails the minimization of the total cost of real power generation at various stations while satisfying the loads and the losses in transmission links. Real power allocation at generator buses, constitute an economic factor in power system operation **[1]** .This problem of allocation can be partitioned into two sub-problems.

They are;

A) Optimum Allocation(Commitment) of generator units at each generating station at various station load levels including load sharing among committed generators

B) Optimum allocation of generation to each station for various system load levels.

The first problem that is (a) in power system is called the 'Unit Commitment (UC)' problem. The second is 'Load scheduling' problem **[1]**. The Unit commitment problem must first be solved before the Load scheduling problem. This paper focuses on the first problem that has to do with the allocation of power in the power system.

There are several techniques already developed to solve the problem of optimum allocation of generator units. They are discussed as follows;

Optimization Methods for Power Allocation in Power System

Major available methods for unit commitment can be grouped as follows **[1];**

i) Deterministic techniques

ii) Meta-heuristic techniques

The deterministic technique can also be regarded as the mathematical method or the Traditional method for optimization. There are a wide range of mature mathematical programming technologies, Such as linear programming (lp)/interior point (ip) method and quadratic Programming (qp), non-linear programming (nlp), decomposition technique, Integer and mixed integer programming, dynamic programming (dp)[2].All these methods already listed may not be able to provide an optimal solution hence they get stuck at local optimal**[3]**. The Meta-heuristic approaches include Expert system, Fuzzy logic, Artificial Neural Network, Genetic Algorithm, and Evolutionary Programming, Simulated annealing, Tabu search, memetic algorithm and Particle Swarm Optimization method**[1]**.They can also be called stochastic optimization techniques**[4].** Unlike the (PSO), most of the stochastic optimization techniques are slow in providing a near global solution [**3**]. Hence the Particle swarm technique is proposed in this paper.

Mathematical Formulations

The fuel cost function equation for units in a power system can be represented as;**[3]**

$$F_i(P_i)= a_iP_i^2+ b_iP_i+ c_i \text{ ....(1)}$$

Where $P_i^{min} \leq P_i \leq P_i^{max}$

Fi is the cost function of generator *i*; a_i, b_i, c_i are cost coefficients of generator i.

'a_i'is in ₦/MW^2

'b_i'is in ₦/MW

c_i is in ₦

P_i is the real power output of generator i.

The total generation should meet the total demand and transmission loss.

The transmission loss can be determined from either b_{mn} coefficients or power flow.**[5]**

$$\sum_{i=1}^{n}(P_i)=D+P_l \text{...2}$$

This equation 2 gives the total generated power with 'P_l'as transmission loss, 'D' as total demand and 'n'as the number of generation units.

Particle Swarm Optimization

Particle Swarm Optimization technique, searches the problem domain by adjusting the trajectories of moving points in a multidimensional space. The Individual particles are moving toward the global points through the interactions of the position and velocity of each Individual, their own previous best performance and the best Performance of their neighbors **[6].** Particle Swarm Optimization has been developed through simulation of Simplified social models. The features of the method are as Follows **[7][8]**:

(a) The method is based on researches about swarms such as Fish schooling and a flock of birds.

(b) It is based on a simple concept. Therefore, the Computation time is short and it requires few memories.

(c) It was originally developed for nonlinear optimization Problems with continuous variables.

According to the research results for a flock of birds, birds find food by flocking (not by each individual). The Observation leads the assumption that every information is shared inside flocking. Moreover, according to observation of behavior of human groups, behavior of each individual (agent) is also based on behavior patterns authorized by the Groups such as customs and other behavior patterns According to the experiences by each individual. The assumption is a basic concept of PSO. PSO is basically developed through simulation of a flock of birds in two dimensions Space **[9]**. The position of each agent is represented by x-y axis position and the velocity (displacement vector) is expressed by v_x (the velocity of x-axis) and v_y (the velocity of y-axis). Modification of the agent position is realized by using the position and the velocity information. Searching procedures by PSO based on the above Concept can be described as follows:

A flock of agents optimizes a certain objective function. Each agent knows its best value so far (pbest) and its x-y position. Moreover, each Agent knows the best value in the group (gbest) among Pbests, namely the best value so far of the group. According to Hirotaka Yoshida and Yoshikazu Fukuyama in their work on 'Particle swarm Optimization for reactive power and voltage control considering Voltage security accessment', the modified velocity of each agent can be calculated using the Current velocity and the distance from pbest and gbest as Shown below:

$$v_i^{k+1}=w_i v_i^k+c_i rand*(pbest_i-s_i^k)+c_2 rand*(gbest-s_i^k) \quad \ldots\ldots 3$$

v_i^k : Current velocity of agent i at iteration k.
v_i^{k+1} : modified velocity of agent i
rand : random number between 0 and 1
s_i^k :current position of agent i at iteration k
$pbest_i$:personal best of agent i
gbest :best of the group
w_i :Weight function for velocity of agent i
c_i :weight coefficients for each term

Using the above equation, a certain velocity that gradually gets close to pbests and gbest can be calculated. The current Position (searching point in the solution space) can be Modified by the following equation given by Hirotaka Yoshida and Yoshikazu Fukuyama:

$$S_i^{k+1} = S_i^k + V_i^{k+1} \quad \ldots\ldots 4$$

S_i^k : current searching point
S_i^{k+1} : modified searching point
V_i^{k+1} : modified velocity

The searching space of D-dimension, and 'm' particles, the ith particle is represented by a D-dimensional X_i (i=1, 2, 3, 4…m) vector which means that the particle locates at ;**[10]**
$X_i = (X_{i1}, Xi_2, Xi_3, \ldots X_{iD})$ for (i=1,2,3,…m) in the search space.[10]
The position of each particle is a potential solution. The particles fitness is thus calculated by its position in a designated objective function. The higher the fitness, the better the X_i.The ith particles flying velocity is also the D-dimensional vector denoted as;
$V_i=(v_{i1}, v_{i2}, v_{i3} \ldots v_{iD})$ for (i=1,2,3…..m),
the best position of the particle is denoted by;
$P_i= (p_{i1}, p_{i2}, p_{i3} \ldots p_{iD})$
The best position for the colony is represented as;
$P_g= (p_{g1}, p_{g2}, p_{g3} \ldots p_{gD})$

Hence, the algorithm can be performed thus;
$X_i(k+1)=x_i(k) + v_i(k+1)$................................5
$V_i(k+1)=wv_i(k) + c_1r_1(p_i-x_i(k)) + c_2r_2(p_g-x_i(k))$.......6
Where i= 1,2,3,…m,
W is the inertia coefficient which is constant in the interval [0, 1],
C_1 and C_2 are the learning rates which are non-negative constants,
r_1 and r_2 are generated randomly in the interval [0,1]
The termination Criterion for the iterations is determined according to whether the maximum generation or a designated Value of the fitness of p_g is reached.
The algorithm already stated can be considered as the conventional Particle Swarm Optimization which is applicable to continuous problem.

Formulation of Power Allocation Optimization by PSO

Each generating unit is allocated a certain amount of power to satisfy the specified demand at the start of the search. The power allocation is based on the upper and lower limit of the generating unit. As the search progresses, these values change until the group best point is reached. During the search, an optimized cost (minimum cost of generation) is also found. The loss in transmission is also considered.

Case Studies

To verify the feasibility of the proposed method of optimization, a power system with various demands is tested. Some parameters are assigned before PSO is used. These parameters include;
i) Number of particles=100
ii) Dimensions=3
iii) Inertia weight=0.4
iv) Maximum Iteration=100000

Case 1

This system comprises of 3 generating units and the input data of 3-generator system are given in Table 1. Here, the total demand for the system is set to 200MW.

Table 1:Data For Test Case I (3-Unit System)

Unit	a(₦/MW^2)	b(₦/MW)	c(₦)	$P_{i(min)}$(MW)	$P_{i(max)}$(MW)
1	0.0650	7.77	650	30	100
2	0.0512	8.25	800	45	125
3	0.0422	8.95	950	50	150

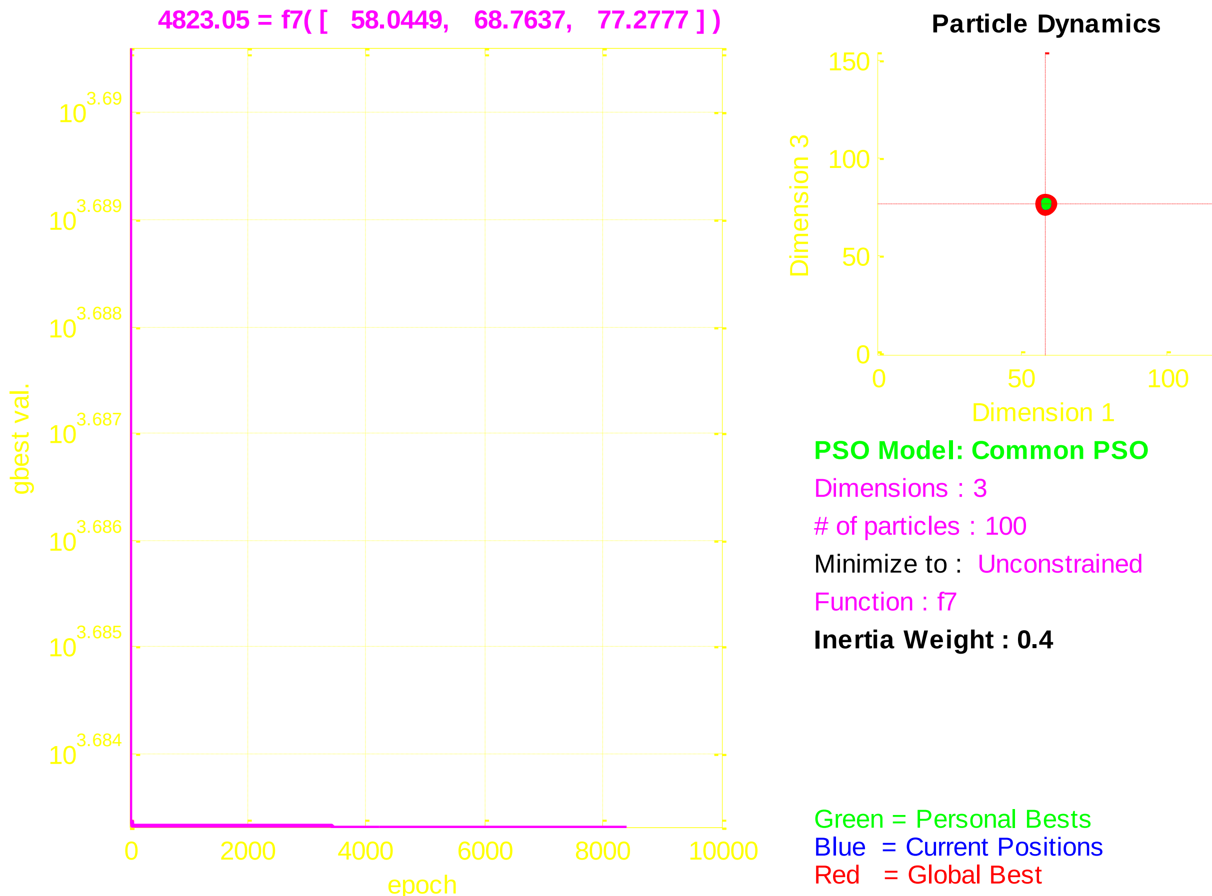

Fig 1.The graph of gbest against epoch

From the graph,it is clear that the optimized power allocated to the three units are as follows ;

Unit one : 58.1458
Unit two :68.6545
Unit three:77.2857

The total power allocated is 204.086MW.This is because the transmission losses were considered during the optimization process. Hence that loss is 4.086MW.

The total optimized cost for the generation of 200MW from the system described above is ₦4823.05.This can also be seen from the graph.

CONCLUSION

This paper presents a Technique for the optimization of Real and Reactive power allocation.The optimization began with the formulation of a non-linear problem. The proposed method utilizes the fuel cost coefficient of the generators, transmission losses upper limit and lower limit of the various generating units to optimize power allocation. A Power system with three generating units is considered. An assumed load demand of 200MW was used to compute the power allocation of the 3 generating units as well as the optimized operational cost.

Generator 1 with upper and lower limits of 100MW and 30MW respectively was allocated 58.0490MW.
Generator 2 with upper and lower limits of 125MW and 45MW respectively was allocated 68.7637MW.
Generator 3 with upper and lower limits of 150MW and 50MW was allocated 77.2777MW.
The method is of importance for Power system planning and operation.

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