Reduction of power generation cost in generating station using IWO algorithm

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Abstract There are several units operating in the power generating station for satisfying the demand. But operating all units for the whole the day is not favour. So Unit Commitment (UC) problem always insisting on reducing the generating cost of the total operating units in the generating station by switching ON/OFF the units depending upon the load requirements. Most of the power stations uses Merit Order Scheduling for selecting the operating units in which the units are selected according to the ascending order of each units production cost which will lead to more wastages. In this project one of the evolutionary algorithms called Invasive Weed Optimization (IWO) Algorithm , a novel numerical stochastic optimization method inspired by colonizing weeds has been introduced for optimizing the operating cost of the power generating units, which gives more accurate result for reducing the generating cost and thus gives a better optimum solution.

Keywords— fuel cost, constraint, Unit commitment, Iwo, PSO ,comparison, optimization.

INTRODUCTION

In a power generating station, the main objective is to achieve the most economical power generation with satisfying the demand. Unit Commitment is used to select the generators in such a way that to satisfy the maximum demand with minimum generation cost. The unit commitment problem (UCP) is one of the high dimensional non linear most essential problem occurring in the power system. So it is necessary to solve this problem in an efficient way. Today's shortage of energy crises insists of developing many optimization technique for solving this unit commitment problem. Several algorithms like Genetic Algorithm (GA), Shuffled Frog Leaping Algorithm (SFLA), Particle Swarm Optimization (PSO) and others are successfully used for the unit commitment problem solution.

Even though GA is found to be efficient in global optimum searching, its running time is very long and limiting its usage. PSO keeps on tracking the information of the position and velocity of the particles. It is not employing any evolutionary operators like mutation and crossover and also it is easy to understand than GA. The control parameters of particle swarm optimization algorithm are number of particles, dimension of particles, maximum number of iteration, learning factors c_1 and c_2 and range of particles. Latterly the derivative free_ optimization algorithm called Invasive Weed Optimization (IWO) algorithm is developed which imitates the natural behaviour of the weeds colony. Here IWO and PSO are used to solve the Unit Commitment Problem (UCP) and comparison is made between IWO and PSO based upon its cost efficiency for UCP with 100 units of generators in the generating station using MATLAB programming.

PROBLEM STATEMENT

The power system network delivers hundreds of GWh of energy from the power generating stations to the power consumers. But the power demand varies for the whole day and its prediction is a tough process. So to ensure the economical and efficient power system with reliable power delivery there should be a careful schedule of operating units is required. Such ON/OFF scheduling the generating units is known as Unit Commitment. Since hundreds of units operating in the power station, it is a large scale optimization problem.The power generating has the following constraints are:

Power Balance Constraint:

Sum of the generated power of the power station at each hour must be equal to the demand requirement for the corresponding hour.

$$\sum_{k=1}^{N} P(k,t)\, U(k,t) = P(l,k)$$

Power generation limit:

There is a limit of power generation for all the generators

$$P(k,min) \le P(k) \le P(k,max)$$

Minimum Up Time (MUT):

The committed units must require minimum time for the units to be turned off and goes to offline.

$$T^{Online}(k,t) \ge MUT(k)$$

Minimum Down Time (MDT):

The decommitted units must require a minimum time for the units to be turned on and comes to online.

$$T^{Offline}(k,t) \ge MDT(k)$$

Spinning Reserve:

Spinning reserve means the total power generation by all the units in the power station minus the sum of demand requirement and power loss.

$$\sum_{k=1}^{N} P(k,t,max)\, U(k,t) \ge P(l,t) + L(t)$$

OBJECTIVE FUNCTION

The objective function of unit commitment is to minimize the total power generating cost, FC, of the generating power from NU units over a particular time, TC. The total power generating cost from each generator for a given time period is the sum of fuel cost, C_k and the start-up cost, S_K during the given period.

The fuel cost, F_k, of the generator with output power, P_k, is,

$$Fk(Pk) = a_k + b_k P_k + c_k P^2$$

Where a_k, b_k, c_k are the cost coefficient of the units.

The start up cost, SC_k, of the generator depends on the unit's switched off time, $T_{offtime}$, before it start up.

$$SC(k) = \sigma k + ћ_k (1-e^{(-Tofftime,k/zk)})$$

Where σk, represents hot start up cost, $ћ_k$, represents cold start up cost. Then the total operating cost, TOC_T, for a time period, T, is the addition of the power production costs and the generator start up costs.

$$TOC_T = \sum_{t=1}^{T}\sum_{k=1}^{N} PC(k,t)U(k,t) + SC(k,t)[1-U(k,t-1)]U(k,t)$$

The fuel cost, C_k, depends on the generation of power $P_K(t)$ in the generating station. The start-up cost, S_K, depends on the unit state X_K, which means that the number of hours the generating units are either in ON or OFF state and U_K is the decision variable in discrete form which indicates whether the generating unit at the time t is either 1(up) or -1(down) from the generating unit at time t+1

INVASIVE WEED OPTIMIZATION

Bio inspired algorithms including evolutionary algorithms, swarm based algorithms and ecology based algorithms are the new revolution in solving optimization problem. Invasive Weed Optimization (IWO) is one of the ecology based bio inspired algorithms which is a stochastic search algorithm proposed by Mehrabian and Lucas in 2006 which simply imitates the natural behaviour of weeds in colonizing and searching place for growth and reproduction of the plants.

In IWO, the search space is represented as a vector in D dimensional space with the control parameters as weed population size, modulation index and standard deviation. The distinctive properties of IWO than other evolutionary algorithms are its method of reproduction, spatial dispersal and competitive exclusion. The process of IWO starts with initialization of a population which is the initial solution over the solution search space. Then the members in the population, based on the fitness, produce seeds. These produced seeds then randomly dispersed over the S dimensional search space by distributed random numbers with mean equal to zero and changing standard deviation. The equation of standard deviation for each generation is given as :

$$\sigma_{itera} = \{ [(I_{max} - I)^{nd} / (I_{max})^{nd}] * (\sigma_{initial} - \sigma_{final}) \} + \sigma_{final}$$

Where I_{max} is the maximum number of iteration , σ_{itera} is the standard deviation at the particular current iteration and nd is the non-linear modulation index.

The steps of the IWO algorithm are explained as below:

Initialization

Initialization starts with inclusion of the initial solution population being scattered randomly over the S dimensional solution space.

Fitness Evaluation

Evaluate the fitness of individual plants and provide rank to the population based on their fitness.

Reproduction

Allow the plants to produce seeds according to on its own and the colony's lowest and highest fitness. This leads to concentrate on the highest fitness values in the search space and so the convergence increases towards the optimum value. The number of seeds produced by the weeds is based on the following equation:

$$Wn = [(fit - fit_{min} / fit_{max} - fit_{min}) * (WS_{max} - WS_{min})] + WS_{min}$$

where, fit is the present weed's fitness. fit_{max} and fit_{min} respectively stands for the maximum and the least fitness of the present population. WS_{max} and WS_{min} respectively stands for the maximum and the least weed's value.

Spatial Dispersal

The produced seeds are being scattered randomly over the S dimensional problem search space by normally distributed random numbers with mean equal to zero but changing variance. This is the condition required for staying the seeds near the weeds.

Competitive Exclusion

By invasive reproduction, the maximum number of seeds reached after certain iteration.. When each and every seeds found their position in the S dimensional search space, these seeds and the weeds will be ranked together. Since they have invasive nature, the lowest fitness weeds get eliminated while the highest fitness weeds only stay back and repeated.

Terminating criteria

When the number of iterations reached to I_{max} (maximum number of iteration), then the algorithm gets terminate.

PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a stochastic method of population based search and is used for solving optimization problem. It takes the idea of social psychological behaviour of the swarm intelligence and applied it into many engineering optimization problems. This algorithm was first introduced by James Kennedy and Russell.C.Eberhart in 1995. In PSO, a swarm (group of fishes, group of horses, group of birds, etc.,) consists of many particles (individuals) and each has a potential solution. A particle has its own position and velocity which will keep on changing for obtaining the optimized output.

Velocity updating equation:

$$V_k^{s+1}(t) = B * V_k^{s}(t) + C1*rand * (P_{bk}^{RS} - P_k^{RS}) + C2*rand * (P_{gk}^{RS} - P_k^{RS})$$

Position updating equation:

$$P_k^{RS} = P_k^{RS} + V_k^{s+1}(t)$$

Where V(t+1) is the updated velocity of the particle in the subsequent iteration, V(t) is the velocity of the particle in the present iteration, B is the inertial transitive which shows the effect of the particle's personal experience on the same particle's next position changing, P_{bk}^{RS} is the neighbourhood best position, V_k^{S} is the particle's current position, C1*rand is the evenly scattered number within the interval of [0,C1] and C2*rand is the evenly scattered number within the interval of [0,C2].

The followings are the processing steps of PSO:

Initialization

Initially the particles has to be selected arbitrarily as initial particles and then initialised the initial population. The swarm size has its limit as K_p*k , where K_p is the total number of particles in the swarm and k is the number of stages.

Velocity Updating

Velocity is updated by considering the particle's current velocity and the particle having best fitness function in the swarm. Velocity updating is done by using the equation (2).

Position Updating

Position updating for each particle is done by summing up the updated velocity and the particular position of the particles in the swarm.

COMPARING RESULTS

The performance of IWO and PSO for a 100 units generating system satisfying 24 hours demand is compared in terms of cost and convergence speed for solving the unit commitment problem is done and is shown in the table 1. The MATLAB program for a 100 units generating system for committing the units using both PSO and IWO technique is written and its performance is shown in the table 1. From that it is shown clearly that the IWO is cost efficient than PSO for committing the units in the generating station containing 100 generating units. Also the IWO converged very quickly with convergence speed 130 seconds than the PSO which is with 168 seconds due to its better performance. The number of iteration required for reaching the optimum solution is less for IWO than PSO

PSO ($)	IWO($)
5263300	5252300

Table 1 Cost comparison of PSO and IWO

CONCLUSION

In this paper the performance comparison of the Invasive Weed Optimization and Particle Swarm Optimization technique is done for cost efficient and convergent speed for a 100 units system satisfying 24 hours demand. From the result it is found that the convergence speed of IWO is more than PSO algorithm and so IWO is more reliable than PSO for optimum result. IWO is not only robust but also it is easy to understand its steps and process. This paper shows that IWO reduces the execution time along with the optimized result with quicker convergence speed than the PSO algorithm.

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