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Optimal Power Flow using Particle Swarm Optimization

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ABSTRACT: The particle swarm optimization is a meta-heuristic method that can optimize of a complex system of electric distribution. In this article, the author will study first, the electric distribution system, second, the method of PSO. Then, the results of the research will be shown. Finally, a brief solution will be made.

KEYWORDS: Particle swarm optimization, Power loss minimization, Reactive power, Voltage control, Voltage stability

I. INTRODUCTION

The optimal power flow is one of the nonlinear constrained and occasionally combinational optimization problems of power systems. The optimal power flow problems have been developed continually since its introduction by Carpentier. Optimal power flow problem solution aims to optimize objective function via optimal adjustment of the power system control variables while satisfying both equality and inequality constraints OPF problem has been solved by several optimization methods such as nonlinear programming, quadratic programming and linear programming.

These methods have failed to handle non-convexities and non-smoothness problems. And evolutionary algorithms have success in solving these problems. Recently, a new evolutionary computation technique called PSO has been proposed. PSO is a derived population-based optimization technique first introduced by Eberhart and Kennedy based on the sociological behaviour associated with the bird flocking and fish behaving.

It takes into consideration the global and local information to determine its flying direction at the next step. PSO has been successfully applied to several optimizing problems such as reactive power and voltage control, economic dispatch and determining generator contributions to transmission system. The original PSO is developed to solve continuous problems. After a little modification it can handle continuous and discrete variables easily.

The proposed algorithm is an unconstrained optimization method and to include the constraints the penalty factor approach is used to convert the constrained optimization to an unconstrained optimization problem.

II. METHODOLOGY

Definition

The process of finding optimal values for the specific parameters of a given system to fulfill all design requirements while considering the lowest possible cost is referred to as an optimization. Optimization problems can be found in all fields of science.

Conventional optimization algorithms (Deterministic algorithms) have some limitations such as : Single-based solutions, Converging to local optima, Unknown search space issues.

To overcome these limitations, many scholars and researchers have developed several metaheuristics to address complex/unsolved optimization problems. Example : Particle Swarm Optimization, Grey wolf optimization, Genetic algorithm..

The Introduction to Particle Swarm Optimization (PSO) article explained the basics of stochastic optimization algorithms and explained the intuition behind particle swarm optimization (PSO).

Advantages and disadvantages

Advantages of PSO :

- Insensitive to scaling of designs variables.
- Derivative free.
- Very few algorithm parameters.
- Very efficient global search algorithm.
- Easily parallelized for concurrent processing.

Disadvantages of PSO :

- Slow convergence in the refined search stage (Weak local search ability).

Mathematical model

- Each particle in particle swarm optimization has an associated position, velocity, fitness value.
- Each particle keeps track of the particle_bestFitness_value particle_bestFitness_position.
- A record of global_bestFitness_position and global_bestFitness_value is maintained.

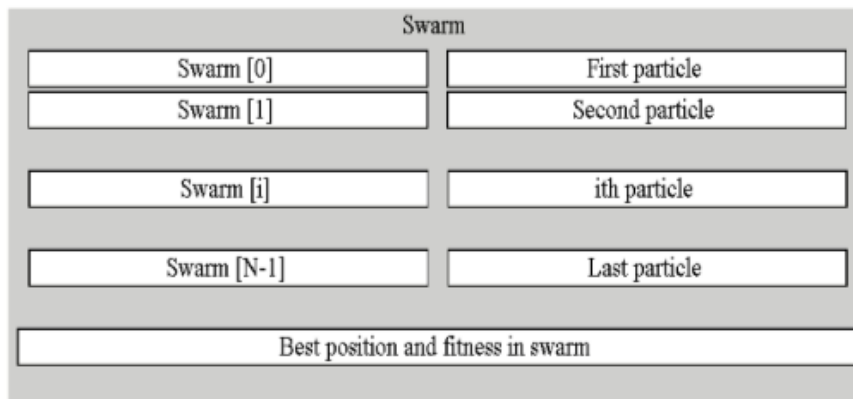


Fig. 1 Data structure to store Swarm population

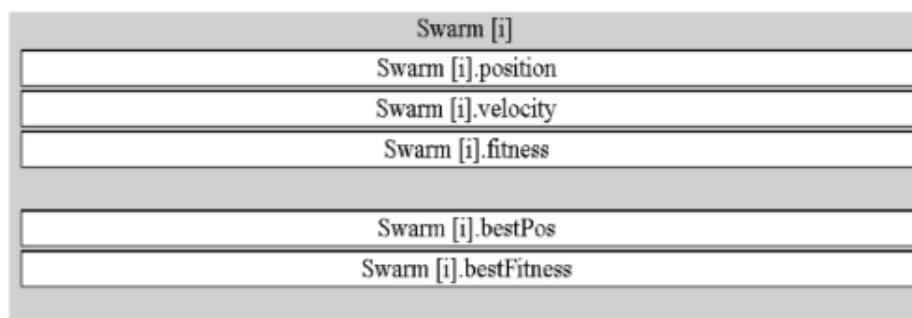


Fig. 2 Data structure to store ith particle of Swarm

Algorithm

Step1 : Randomly initialize Swarm population of N particles X_i ($i=1, 2, \dots, n$)

Step2 : Select hyperparameter values $w, c1$ and $c2$

Step 3 : For Iter in range(max_iter): # loop max_iter times

For i in range(N): # for each particle

a. Compute new velocity of ith particle

$$\text{swarm}[i].\text{velocity} = w * \text{swarm}[i].\text{velocity} + r1 * c1 * (\text{swarm}[i].\text{bestPos} - \text{swarm}[i].\text{position}) + r2 * c2 * (\text{best_pos_swarm} - \text{swarm}[i].\text{position})$$

b. Compute new position of ith particle using its new velocity

$$\text{swarm}[i].\text{position} += \text{swarm}[i].\text{velocity}$$

```

c. If position is not in range [minx, maxx] then clip it
if swarm[i].position < minx:
swarm[i].position = minx
elif swarm[i].position > maxx:
swarm[i].position = maxx
d. Update new best of this particle and new best of Swarm
if swaInsensitive to scaling of design variables.rm[i].fitness < swarm[i].bestFitness:
swarm[i].bestFitness = swarm[i].fitness
swarm[i].bestPos = swarm[i].position
if swarm[i].fitness < best_fitness_swarm
best_fitness_swarm = swarm[i].fitness
best_pos_swarm = swarm[i].position
End-for
End -for
Step 4: Return best particle of Swarm

```

Problem formulation

The optimal power flow is a problem that can be threat with different methods. Particle swarm optimization is a method that ask if there is any demand of energy. If yes, we optimize the distribution of energy in the system.

So, we can visualize the results is the next section with a brief discussion of the performances of this algorithm regarding the optimal power flow.

III. EXPERIMENTAL RESULTS

Dataset summary

Table 1 Dataset

Date	Time	Active power	Reactive power	Voltage	Intensity
16/12/2006	17:24:00	4.216	0.418	234.84	18.4
16/12/2006	17:25:00	5.360	0.436	233.63	23.0
16/12/2006	17:26:00	5.374	0.498	233.29	23.0
16/12/2006	17:27:00	5.388	0.502	233.74	23.0
...
27/12/2006	18:42:00	1.592	0.124	238.78	6.6
27/12/2006	18:43:00	1.510	0.000	238.21	6.2
27/12/2006	18:44:00	1.502	0.000	237.64	6.2
27/12/2006	18:45:00	1.656	0.000	237.71	7.0
27/12/2006	18:46:00	1.688	0.000	238.2	NaN

Global active power

As a result, we obtain the following plot.

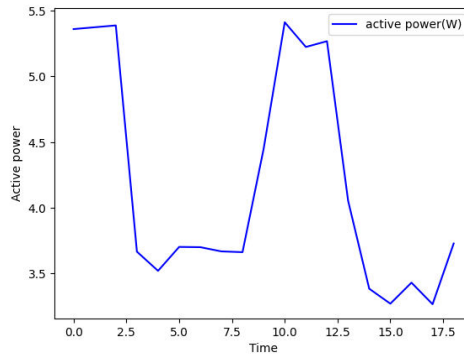


Fig. 3 Active power

Global reactive power

As a result, we obtain the following plot.

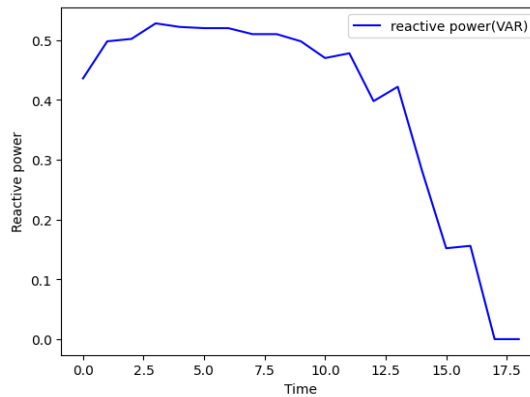


Fig. 4 Reactive power

Global intensity

As a result, we obtain the following plot.

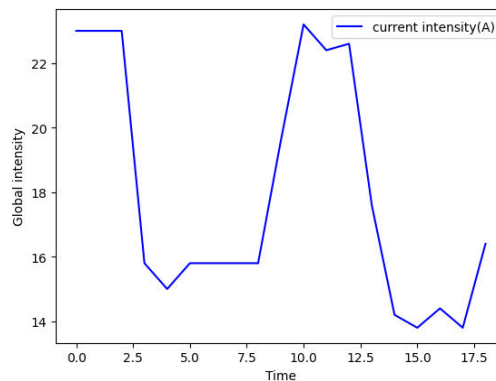


Fig. 5 Global intensity

Results of PSO algorithm

The fitness of the swarm of our dataset is declining when augmenting the iterations.

We found the following plot.

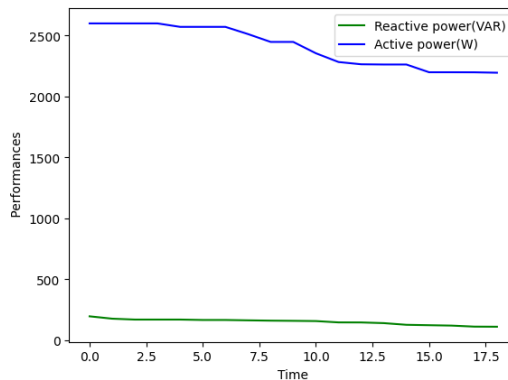


Fig. 6 Fitness of the swarm

The best solution is visualizing in the following graph.

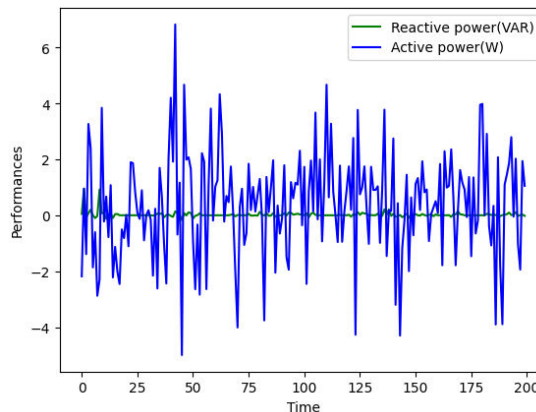


Fig. 7 Swarm best solution

The figure is visualizing the capacitors value value in order to find the best value for the compensation of reactive power.

Discussion

The application of particle swarm optimization for electric distribution system leads us to find the best configuration of capacitors to compensate the reactive power.

Generally, the method gives us a good performance. Thus, it is an automatisations of allowing the capacitors value in order to optimize the system.

But, the configuration should take in consideration the protection constraints in order to assure the security of the electric system.

In the literature, there are other methods like multi objective pareto, loss minimization, newton method..

IV. CONCLUSION

The article discusses the particle swarm optimization for the optimization of electric distribution system. The best solution is the swarm with the best position, velocity and fitness value to minimize the best the reactive power.

As a conclusion, we can optimize the energy of consumption via a swarm of capacitors value to have the minimum of reactive power and a reasonable power factor.

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