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Optimal power flow calculation based on improved particle swarm optimization

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ABSTRACT

In order to study the efficient and feasible algorithm of solving power system optimal power flow,the paper discusses and improves the particle swarm optimization (pso) algorithm which has the convergence speed and global search ability; the introduction of penalty function to deal with the constraints of the optimal power flow problem, MATLAB simulation platform is applicated to program improved particle swarm optimization (pso) algorithm and the traditional Newton algorithm, calculating the result of IEEE - 30 nodes standard system of optimal power flow, and comparing the result of two algorithm can highlight the particle swarm algorithm in solving the optimal power flow calculation problem.

KEYWORDS

Power system; Optimal power flow; Particle swarm algorithm; Newton algorithm; Penalty function.

INTRODUCTION

American social psychologist j.k. ennedy and electrical engineer R.E berhart put forword the particle swarm algorithm (PSO) in 1995[1], according to the principle of bionics, PSO imitates the behavior of herds groups,such as fish and flocks and so on, at the same time references biologist F.Heppner's biological group model and researchs into the idea of evolutionary computation, which is an efficient optimization algorithm. Due to the convergence of particle swarm algorithm is easy to implement, algorithm has good robustness[2] and the computing speed is faster than traditional algorithms, which suitablly solves nonlinear and multidimensional problem with constraint condition of complex optimization, therefore it has been widely applied to the practice of science. In recent years, particle swarm optimization (pso) algorithm has been widely applied in controlling voltage of the power system, power system state estimation, the active power distribution and optimal power flow calculation and so on.

THE PARTICLE SWARM ALGORITHM AND IMPROVED

The standard particle swarm optimization (pso) algorithm

Standard particle swarm optimization (PSO) firstly initializes the known particles group in the solution space randomly, the number of optimization problems' variables determines the space's dimensions, after each particle has the initial position and velocity, they use the method of iterative optimization to track two "extreme" so that particles can update the space position and flying speed[3]. Assuming in n-dimensional search space, the current position of the i-th particle (particle i) is denoted as $X_i = (x_{i1}, x_{i2}, \cdots, x_{in})$, the speed of particle i is denated as $V_i = (v_{i1}, v_{i2}, \cdots, v_{in})$,the best location of the particle i until now the number of iterations is denoted as $P_i = (p_{i1}, p_{i2}, \cdots, p_{in})$, so far all particles have experienced best position is denoted the global best position as $P_g = (p_{g1}, p_{g2}, \cdots, p_{gn})$. For each iteration, the particles' optimum formula is as follows:

$$v_{in}^{k+1} = \omega v_{in}^{k} + c_1 r_1 (p_{in} - x_{in}) + c_2 r_2 (p_{gn} - x_{in}) \tag{1}$$

$$x_{in}^{k+1} = x_{in}^{k} + v_{in}^{k+1} \tag{2}$$

In the type: n is dimension;
ω is inertia weight coefficient[4];
c_1 and c_2 are the random constant[5] that greeter than zero and Respectively delegates pass-by individual best solution and the global best solution of acceleration weight coefficient, according to experience, they are generally set between [1.0, 2.0];
r_1 and r_2 [6] are random constants which are set between [0,1].

Improved particle swarm algorithm

Standard particle swarm algorithm can not take into account the convergence speed, global search ability and local search capabilities,so this paper proposes an improved particle swarm algorithm; ω has a great influence on search ability, when it is bigger, it is conducive to escape from local minima point so that algorithm can search globally ; when it is smaller, it is conducive to locally search accurately, to overcome the disadvantage that the PSO algorithm is easy to fall into local minimum value early and occur late shocks around the global best solution easily[7], using a linear weight coefficient to make the weight coefficient decrease from maximum $\omega_{\max}$ to minimum $\omega_{\min}$ linearly, the calculating formula is as follows:

$$\omega = \omega_{\max} - \frac{t \times (\omega_{\max} - \omega_{\min})}{t_{\max}} \tag{3}$$

In the type: $\omega_{\max}$ is the maximum of ω, $\omega_{\min}$ is the minimum of the ω, usually $\omega_{\max}$ =0.9、 $\omega_{\min}$ =0.4 ; t is the step of current iteration, $t_{\max}$ is the Biggest step of iteration.

c_1 and c_2 have a decisive role on empirical information of the particle itself and the impact the experience information of other particles on particles' trajectory, which highlights the characteristics of information exchange between the particle swarm. When c_1 is bigger, it will lead to particle search scope locally, When c_2 is bigger, it will lead to early convergence in local minimum; so according to the experience, $c_1 = c_2$ =1.5, the algorithm can effectively regulate flying speed so that particles can achieve the balance between global search and local search.

POWER SYSTEM OPTIMAL POWER FLOW

The objective function of optimal power flow

Optimal power flow (OPF) usually uses minimum of system operation cost or network losses as the objective function[8-9], this paper bases on minimum network losses as the objective function, the mathematical model is as follow :

$$\min .P_{loss} = \sum_{i=1}^{n} \left(P_{Gi} - P_{Di} \right) \quad \textbf{(4)}$$

In the type: P_{loss} is system network losses;

P_{Gi} is the active power of the generator i;

P_{Di} is the active load of the node i.

The constraints

The equality constraints is as follows:

$$P_{Gi} - P_{Li} - P(V,\theta) = 0 \quad \textbf{(5)}$$

$$Q_{Gi} - Q_{Li} - Q(V,\theta) = 0 \quad \textbf{(6)}$$

In the types: P_{Gi} and P_{Li} are the active efforts and active load of generator i respectively;

Q_{Gi} and Q_{Li} are the reactive power and reactive load of generator i respectively;

$P(V,\theta)$ and $Q(V,\theta)$ are the active and reactive network loss respectively;

Type (5), (6) are also node trend equations[10].

The inequality constraints is as follows:

$$S_{ij}^{f} \le S_{ij}^{\max}; S_{ij}^{t} \le S_{ij}^{\max}; \quad \textbf{(7)}$$

$$V_i^{\min} \le V_i \le V_i^{\max}; \quad \textbf{(8)}$$

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max}; \quad \textbf{(9)}$$

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max}; \quad \textbf{(10)}$$

In the types: S_{ij}^{f} and S_{ij}^{t} are the apparent power of transmission lines and terminal service lines respectively, $S_{ij}^{\max}$ is the upper limit of the lines' apparent power ;

V_i is bus voltage, $V_i^{\min}$ and $V_i^{\max}$ are the lower limit and the upper limit of bus voltage respectively;

P_{Gi} is active power of Generator, $P_{Gi}^{\min}$ and $P_{Gi}^{\max}$ are the lower limit and the upper limit of generator's active power respectively;

Q_{Gi} is reactive power of generator, $Q_{Gi}^{\min}$ and $Q_{Gi}^{\max}$ are the lower limit and the upper limit of generator's reactive power respectively.

Building a penalty function

Using penalty function method to deal with constraints[11]and constructe a suitable objective function for particle swarm optimization; In order to improve the voltage characteristic[12],this paper constructes the objective function by adjusting the difference between bus voltage unit and voltage amplitude 1.0 and system network loss to achieve the minimum, the mathematical mode is as follow :

$$f = P_{loss} + \omega \sum_{i \in M} |V_i - 1.0| \tag{11}$$

In the types: M is the set of all the nodes that voltage amplitude is not 1.0.

ALGORITHM IMPLEMENTATION

The improved particle swarm algorithm has strong searching ability and high searching accuracy, it is not easy to fall into local minimum ; The optimal power flow calculation contains a large number of constraints that introduced into the original objective function to form a new function, making the original constrained optimization problem into unconstrained optimization problems, so as to simplify the complicated problem. The combination of penalty function and particle swarm optimization (pso),which manipulates the constraint conditions of the optimal power flow problem [12] and simplifies the complicated trend. The algorithm specific steps are as follows:

Input system parameters and the variable limit, the number of iterations $k = 1$;

Initialize the particle's velocity and position ;

The trend and network loss calculation should be made for each particle's with the fast decoupled method;

To assess the fitness of each particle, looking for the particle's individual optimal solution and the global optimal solution;

When $k = k + 1$, using the type (3) update ω;

Type (1) is used to calculate the particle velocity at present, and type (2) is used to calculate the particle position, using type (7-10) to dynamically adjust constraints;

Trend and network loss calculation are made by fast decoupled method, reassess each particle fitness and whether updating each particle's P_i and P_g or not are determined according to the type (11);

If $k \le k_{\max}$, then end operation; Otherwise, return to step (5).

THE EXPERIMENTAL SIMULATION

In order to structure true imitation method,the algorithm uses Matlab to deal with 30 nodes - IEEE standard systems[14],Particle swarm algorithm parameters are set as follows: $t_{\max} = 80$、$\omega_{\max} = 0.9$、$\omega_{\min} = 0.4$、$c_1 = c_2 = 1.5$,the particle number is 50. The specific experimental results of Newton method[12] and the improved particle swarm optimization (pso) algorithm are shown in figure 1, figure 2, TABLE 1. In the figure1 and figure2: the dotted line represents the particle swarm algorithm and the solid line represents the Newton's method.

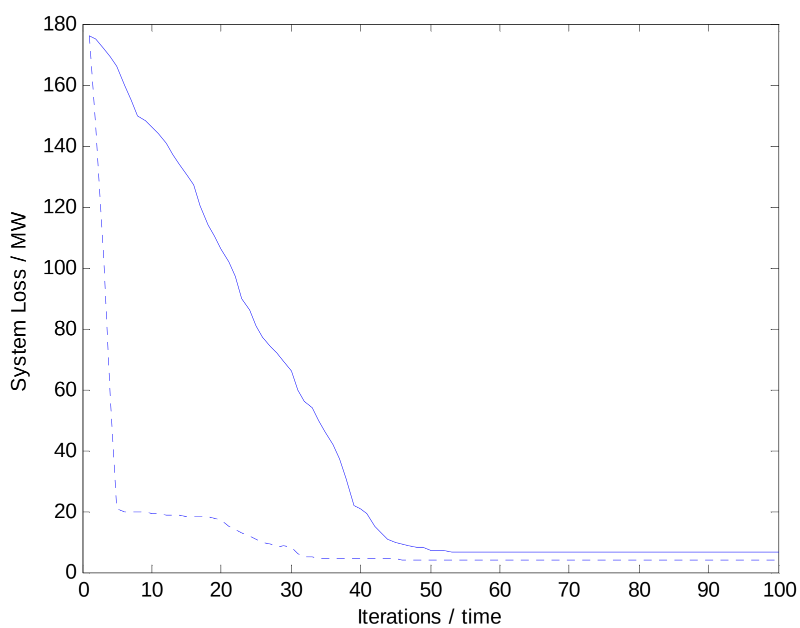

Figure 1: The convergence property of the system network loss curve

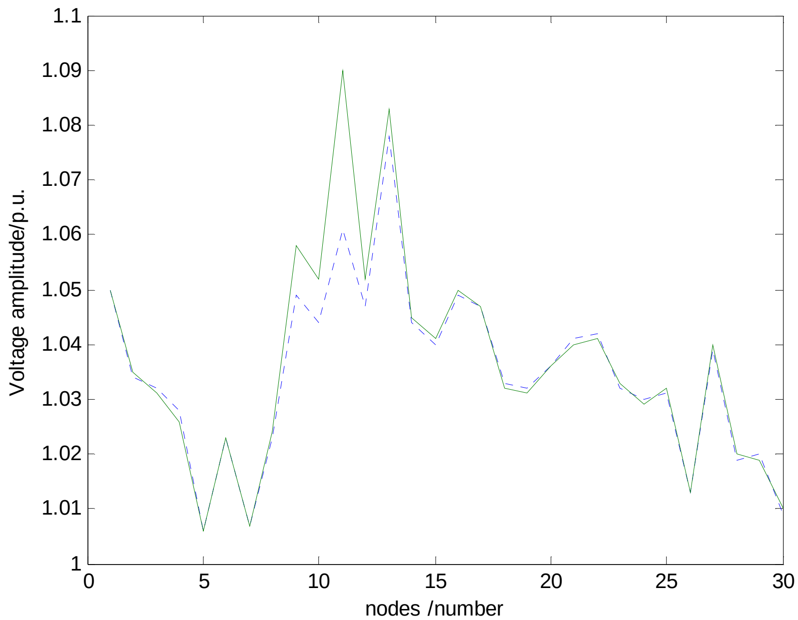

Figure 2: The node voltage characteristic curve of the system

TABLE 1: Results of IEEE-30 Nodes Standard system optimal power flow optimization

Parameter	Improved particle swarm algorithm		Newton's method	
	P_G /MV	Q_G /Mvar	P_G /MV	Q_G /Mvar
G_1	14.13	5.61	41.54	5.44
G_2	47.21	24.96	55.40	25.87
G_3	20.85	16.45	16.20	35.93
G_4	38.40	10.71	22.74	34.20
G_5	22.32	18.02	16.27	16.96
G_6	27.01	25.01	39.91	31.75
The total power generation	169.92	100.76	192.06	150.15
System network loss /MW	3.8342		6.5410	

RESULT AND DISSCUSS

System network loss optimization results of IEEE-30 Nodes standard is shown in figure 1. It can be seen that improved particle swarm algorithm's convergence iteration is 36-th time, But Newton's convergence iteration is 54-th time. It is shown that improved particle swarm optimization (pso) algorithm's convergence speed is faster.

Figure 2 is voltage characteristic curve of IEEE - 30 node system,the voltage amplitudes of two algorithms are compared with each other, it can be seen that the voltage characteristic curve of improved particle swarm algorithm is more stable and Newton's method's voltage characteristic curve is volatile. Thus improved particle swarm algorithm has good voltage stability.

The results of both algorithms are listed in TABLE 1. System network losses of the improved particle swarm algorithm is 3.8342MW, which is 2.7068MW less than Newton's method of system network loss's 6.5410 MW. So the drop is 41.38% ;the total generating capacity of improved particle swarm algorithm is smaller. So it is shown that the improved particle swarm algorithm can effectively reduce the network loss, and system operation is also more economic and reasonable.

CONCLUSION

By comparing the experimental data of the improved particle swarm optimization (pso) algorithm and the traditional Newton method, which highlight that the particle swarm algorithm has the following advantages in solving the optimal power flow problem: Improved particle swarm optimization (pso) algorithm is good at dealing with equality and inequality constraints of current problem; PSO can more accurately find out the optimal power flow calculation results, be simple and easy to implement; The PSO algorithm of the optimal power flow has good numerical stability, faster convergence speed and it can find the global optimal solution of the problem, which is better than traditional Newton algorithm in solving optimal power flow problem.

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