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The Power System State Estimation by Patricle Swarm Optimization Algorithm

Liu Junxiong, Zhang Jianjun, Guo Lihu
The Power Supply Company ,The Daqing Oilfield Power Group. 163453, Daqing, China

Abstract*:* The state estimation is the basic of the power system analysis. The result of power system state estimation is to get the state off power system that is more closer to the real. The least robustness square method is the common method in state estimation. But we find that it is difficult to solve the problem of divergence in practical applications. The particle swarm optimization algorithm will be used in power system state estimation in this particle. It is good for improving the convergence of power system state estimation. Finally using IEEE9 node system prove the validity of this method.

Keywords State estimation; Least robustness square method; Particle swarm optimization algorithm

INTRODUCTION

Power system analysis includes several sections Network topology analysis, state estimation, power flow calculation, etc; where state estimation is the basis of the power flow calculation. There are many state estimation methods, which most commonly used is the least robustness square method. The basic principle of the least robustness square method is to find a set of states variable to get the minimum sum of the variance of network power and measurement. Newton iterative method is used in the process of solution. But we find that this method is very sensitive to the initial value in the actual calculations. Because this method contains the form of the equation is complicated, it is easy to cause iterative divergence. In order to solve the problem, this paper presents the power system state estimation on the basis of particle swarm optimization algorithm.

Weighted least squares solution can be as on a target function optimization problem. Particle swarm optimization algorithm simulates bird's flying. Using the concept of "group'' and "evolution'', according to the operation of individual adaptive value size, which can solve the optimization problem with an objective function effectively[Yan *et al*.,2004]. This method is not high requirements for the initial value, its application to the process of solving the least robustness square method, which is good for improving the convergence of power system state estimation.

LEAST ROBUSTNESS SQUARE METHOD STATE ESTIMATION

Power system dispatching center need to accurately grasp the operation status of the power system, provide the basis for the next decision and enable power system safe and stable operation. There are usually two ways to establish a reliable and complete real-time database, from the way of hardware you can increase measuring equipment and remote device, and improve its precision, speed and reliability, from the way of software you can use the modern state estimation techniques for real-time data processing. But if we put forward higher requirements on the measurement and remote equipment, which can lead to put too much cost on technical and economic. Based on a certain level of hardware, the state estimation technology can give full play to the potential of existing hardware devices to improve the accuracy of data, supplement the shortage of the measuring point and measuring project, eliminate the accidental error information and data, improve the quality and reliability of the whole data system[Liu *et al*.,2004].

The least robustness square method is a common method in state estimation, especially suitable for High Voltage Transmission Network. Because the phase angle of power grid voltage is difficult to measure, while power is easy to measure, so most of power system measured value is a node and branch of the active power and reactive power, which is assumed to be Z voltage amplitude and phase angle of each node is referred to as the state variable, which is assumed to be X , w is defined as a measuring weight parameter, which reflects the accuracy of measurement. $h(x)$ is defined as the power equation of the node and branch, the principle of state estimation is to find a set of state variable X which minimizes the objective function $J(X) = w(Z(X) - h(X))^2$ values [Huang Yanquan, 2004]. This function can achieve the minimum value on partial derivatives of the objective function, which can be expressed as:

Corresponding Author: Guo Lihu, The Power Supply Company ,The Daqing Oilfield Power Group. 163453, Daqing, China.

$$\frac{\partial J(X)}{\partial X_i} = 0 \qquad (1)$$

This is a multivariate nonlinear equations, using Newton's iteration method to solve it.

Using IEEE9 node system as an example for state estimation. System wiring diagram is shown as the following figure:

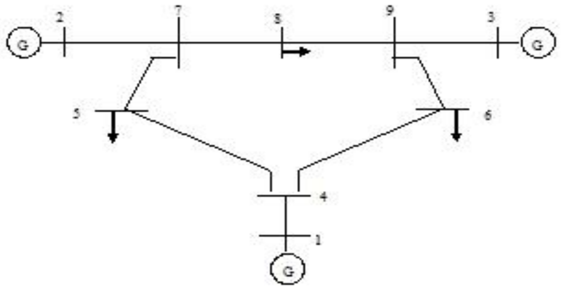

Figure 1. System wiring diagram

The data of power distribution system in the following table:

Table 1. Data of power distribution system

P2=1.63	P45=0.40938
P3=0.85	Q4=0
P4=0	Q5=－0.5
P5=－1.25	Q6=－0.3
P6=－0.9	Q7=0
P7=0	Q8=－0.35
P8=－1	Q9=0
P9=0	Q72=0.09172
P72=－1.62994	Q75=－0.04251
P75=0.86623	Q89=－0.22744
P89=－0.24095	Q54=－0.41907
P54=－0.4068	Q93=0.14955
P93=－0.85001	Q69=－0.08325
P69=－0.59464	Q46=0.00553
P46=0.30705	Q96=－0.14109
P96=0.60818	Q45=0.23365

There is a total of 32 measurements in the above table, while there is a total of 14 state value need to be addressed in this system, redundancy is 2.3, which is accordance with the requirements of the state estimation.

In practical programming, it has been found that Newton Iteration Method has certain requirement for the accuracy of the initial value. Because the state estimation equations are more complicated, which makes the Newton iterative method for the initial value of the higher requirements. After multiple tests, we discovered that iteration convergence appears only when the given initial value and actual value is very close, while slightly bigger deviation will cause iteration divergence. While it is an inevitable problem in using Newton iteration method,unable to try to test value in the state estimation, which requires a more effective method to solve iteration divergence problem to decrease sensitivity of the algorithm for initial value.

The crucial factor of state estimation is optimization of objective function. The particle swarm evolution algorithm have good performance in objective function optimizing, so the particle swarm evolution algorithm can be used in state estimation to enhance convergence of the whole algorithm.

THE BASIC CONTENT OF PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle swarm evolution algorithm was first proposed in 1995, its basic idea is inspired by birds of crowd behavior. At the beginning each birds is flying without a specific target, until there is a bird fly to habitat, when the fitness value of the expected habitat is greater than the value of the expected left in the birds, each bird will leave the birds and fly to habitat. Birds use simple rules to determine the direction of flight and flight velocity. When a bird flying away from the birds fly to the habitat, will cause the around birds also fly to the habitat. These birds will land on this once found habitat, which drive more birds fall in habitat, until the bird communities in habitats .

Particle swarm optimization algorithm regards each individual as a particle in n dimensional search space, this particle in the search space at a certain speed flight. Flight speed adjusting dynamically by individuals and the groups of flight experience.

Let Xi and Vi denote the particle's current position and its corresponding velocity respectively, therefore, the i-th particle is represented as $X_i = (x_{i1}, x_{i2}, \cdots, x_{in})$ and $V_i = (v_{i1}, v_{i2}, \cdots, v_{in})$, the best previous position of the i-th particle is represented as $P_i = (p_{i1}, p_{i2}, \cdots, p_{in})$.

The evolution equation of particle swarm optimization algorithm can be represented as follows:

$$\begin{aligned} v_{ij}(t+1) = v_{ij}(t) + c_1 r_{1j}(t)(p_{ij}(t) - x_{ij}(t)) \\ + c_2 r_{2j}(t)(p_{gj}(t) - x_{ij}(t)) \end{aligned} \qquad (2)$$

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \qquad (3)$$

Where c_1, c_2 is a constant acceleration, generally value between 0 to 2, r_1 , r_2 random numbers between 0 to 1.

From the evolution equation, c_1 can be seen that adjusts particles fly towards its own best location step length, c_2 can be seen that adjusts particles fly toward the direction of the global best position step length. In order to reduce the possibility of the particles away from the search space in the process of evolution, v_{ij} usually within a limited range, that is $v_{ij} \in [-v_{\max}, v_{\max}]$.

Particle swarm algorithm process is as follow steps:

1) Initialize the particle swarm random position and its velocity.
2) Alculate the fitness value of each particle.
3) For each particle, compare its fitness value to the fitness value of its best position p_i, if its fitness value is better, its fitness value is set to be the current best position.
4) For each particle, compare its fitness value to the fitness value of its global best position p_i, if its fitness value is better, its fitness value is set to be the current global best position.
5) According to the evolution equation evolve the position and speed of particles.
6) If have not reached the end condition, back to step 2.

APPLICATION OF PARTICLE SWARM OPTIMIZATION ALGORITHM IN STATE ESTIMATION

Due to the error of the measurement system, therefore can only get the approximate amount of network state. The objective function of the least robustness square method indicates the similarity between the network status and the real quantity. When a network has dozens of measurement, the objective function is the sum of the weighted difference after dozens of square. If this value is very small, the state of the measure is very close to the real state of the network at this time. The fitness value of particle swarm optimization algorithm is this value. At the initial stage of the algorithm, set the unknown quantity of each node of the network voltage phase angle and amplitude of voltage as the initial position of particles, usually the voltage phase angle is zero, the amplitude of voltage is the voltage amplitude balance node. Begin to fitness computation and evolution after setting the initial value. Set the end value of the algorithm, that is, when the global minimum fitness value less than a certain value can be regarded as the end of the algorithm. Generally set this value between 0.05 to 0.1.

Particle swarm evolution state estimation is applied into IEEE9 nodes system, and got a reasonable amount of network state.

To get the ideal results of particle swarm evolution state estimation, there are a few points to note: First, random number can not be used as the initialization data, if the random number as initial data ,the solution will be obtained in the local search space, which may not be what we want. Set voltage magnitude and phase angle of the balance node as the initialization data, then will get the solution near the balance node, which accords with the characteristics of power system, the ideal solution is obtained. Second, the scale and number of steps in the evolution of the population should be appropriate. Generally speaking, the population size in the vicinity of one hundred, evolution steps near five hundred, which can get the ideal solution. Third, two acceleration constants c_1 and c_2 settings in the program to the rational evolution. By testing the reasonable constant acceleration is 1.8.

Table 2. Network state after particle swarm evolution state estimation

Node number	Voltage amplitude	Voltage phase
1	1.04000	0.00000
2	1.02500	0.15244
3	1.02500	0.04175
4	1.01953	−0.042
5	0.98907	−0.073
6	1.00125	−0.074
7	1.02360	0.05255
8	1.01311	−0.011
9	1.02868	0.00042

CONCLUSION

Power system state estimation itself is a huge topic. Power system state estimation is divided into on-line system and off-line system. On-line system has higher requirements of computing speed. Both the traditional least square method and fast decomposition method, the convergence of algorithm is difficult. Particle swarm optimization algorithm of state estimation can effectively solve the problem of the algorithm does not converge, but the computing time will increase a lot. Off-line system requirements for computing speed relatively loose, so the algorithm can be applied to the off-line state estimation.

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