



Using a particle swarm method to optimize the weighting in extension theory for the detection of islanding in photovoltaic systems

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ABSTRACT

This paper proposes a two-dimensional particle swarm optimization (2D-PSO) method for optimizing the weighting in extension theory for the detection of islanding in photovoltaic (PV) power generation systems. Generally, using extension theory to implement and analyze a system with a correlation function would involve constructing a weighting determined by trial and error to help judge the problem's performance. However, the judgment accuracy can be degraded if one uses an inappropriate weighting set. Hence, this paper proposes a weighting determination method for optimizing the performance of the extension method using the 2D-PSO algorithm. Some simulation results are obtained to verify the effectiveness of the proposed islanding detection method. In addition, the simulated results obtained using the proposed 2D-PSO algorithm are also compared with those obtained using genetic algorithm (GA) and evolutionary programming (EP) algorithms in order to reveal the search performance of the proposed method.

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1. Introduction

Islanding detection is a significant PV technique as regards protecting personnel, avoiding equipment damage and maintaining power quality in power systems. There are two classifications of islanding detection techniques: those including passive [1–4] and active detection modes [5–8]. The main passive detection techniques are the voltage phase jump detection method, the frequency changing rate detection method and the detection method based on the third-harmonic distortion of a voltage surge [1]. The main active detection techniques are the active voltage drift method [5], the active frequency drift method [6], the slip mode frequency drift method [7] and the load variation method [8]. A research approach adopting an extension theory based multi-variable method that combines passive and active detection methods to detect an islanding problem in PV power generation systems was introduced in [9]. However, it used a trial-and-error weighting in the extension engineering method to identify seven islanding phenomena: voltage swell, voltage dip, injected harmonic power, normal operation, islanding operation below or above the normal operation limitations and voltage flicker. The trial-and-error weighting method might lead to a wrong judgment problem when dealing with some critical cases.

The evolutionary genetic algorithms (GA) [10,11] and evolutionary programming (EP) [11] algorithms are search algorithms based on the simulated evolutionary process of natural selection, variation, and genetics. The evolutionary algorithms are more flexible and robust than conventional trial-and-error methods. Although a GA approach can provide a near global solution, the encoding and decoding schemes means that it takes a longer time to achieve convergence. However, an EP algorithm uses the control parameters [11], but not their coding, as in the GA approach. In addition, the EP algorithm relies primarily on mutation and selection, but not crossover, as in the GA approach. Hence, considerable computation time may be saved by using an EP algorithm. Although GA and EP algorithms seem to be good methods for solving optimization

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problems, when applied to problems consisting of greater numbers of local minima, the solutions obtained from both methods are just ones near the global optimum ones [11]. Additionally, GA and EP algorithms take long computation times to obtain the solutions for such problems [11]. Like other evolutionary algorithms, the particle swarm optimization (PSO) algorithm starts with random initialization of a population of individuals in the search space [12–16]. However, unlike in other evolutionary algorithms, in PSO there is no direct recombination of genetic material between individuals during the search process. The PSO works on the social behavior of particles in the swarm. Therefore, it finds the global optimum solution by simply adjusting the trajectory of each individual toward its own best location and toward the best particle of the entire swarm at each step. The PSO method is a stochastic search technique with simplicity of implementation and the ability to more quickly converge to a reasonably good solution as compared to other evolutionary algorithms.

On the basis of the above, a 2D-PSO method is proposed in this paper for searching for the optimal weighting in an existing extension islanding detection method [9] for a PV power generation system. Through enlarging the correlation degree difference between two adjacent islanding types, the judgment accuracy of islanding detections can be promoted for a PV generation system.

2. A summary of particle swarm optimization

Particle swarm optimization (PSO) is a stochastic optimization technique developed by Eberhart and Kennedy in 1995, inspired by the social behavior of bird flocking or fish schooling [12]. A kernel concept for the optimization of nonlinear functions using particle swarm methodology is introduced in [13].

The general PSO algorithm first defines the potential solutions, called particles, then moves each of the particles to the next position according to a velocity function, and finally checks whether these potential particles can approach the globally best solution or exactly find it [14]. The following is a pseudo-code for the procedure used to implement the proposed 2D-PSO algorithm:

```

2D-PSO procedure
{
  Define particle numbers ( $N$ ) and maximum iteration number ( $i\_max$ );
  Initialize all particles' positions ( $px_j, py_j$ ) and velocities ( $vx_j, vy_j$ );
  Define all particles' best locations ( $bx_j, by_j$ ) as ( $px_j, py_j$ );
  Define the global best position ( $Gx, Gy$ ) and initialize as (0, 0);
  For  $i = 1$  to  $i\_max$  {
    For  $j = 1$  to  $N$ {
      Calculate the new velocity and position of each particle:
      ( $vx_{j+1}, vy_{j+1}$ ) = velocity( $vx_j, vy_j, bx_j, by_j, px_j, py_j, Gx, Gy$ );
      ( $px_{j+1}, py_{j+1}$ ) = ( $vx_{j+1}, vy_{j+1}$ ) + ( $px_j, py_j$ );
      Calculate the fitness values:
      New performance = fitness ( $x_{j+1}, y_{j+1}$ );
      Current best performance = fitness ( $(px_j, py_j)$ );
      Upgrade each particle's best position:
      If (New performance) > (Current best performance)
        Then ( $bx_j, by_j$ ) = ( $px_{j+1}, py_{j+1}$ );
    }
    Get the best position ( $x_{best}, y_{best}$ ) from all the particles;
    Update global best positions:
    If fitness ( $x_{best}, y_{best}$ ) > fitness ( $Gx, Gy$ ),
      Then ( $Gx, Gy$ ) = ( $x_{best}, y_{best}$ );
    Record new positions and velocities of all particles;
  }
}

```

where the velocity function uses the following two formulas:

$$vx_{j+1} = w * vx_j + \eta_1 * rand(1) * (bx_j - px_j) + \eta_2 * rand(1) * (Gx - px_j)$$

$$vy_{j+1} = w * vy_j + \eta_1 * rand(1) * (by_j - py_j) + \eta_2 * rand(1) * (Gy - py_j)$$

where η_1, η_2 are positive learning factors, w is an inertia weight and $rand(1)$ is a random value from 0 to 1; the fitness function is the user-defined function for reaching the best performance.

The fitness function in the 2D-PSO procedure is based on the input of two random weight numbers into the correlation function of the extension method and then feedback of the result from the fitness subroutine. The running continues for

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