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A NEW APPROCH FOR OPTIMAL DG PLACEMENT (ODGP) IN POWER DISTRIBUTION N ETWORK FOR SOLVING THE OPTIMAL POWER FLOW BY USING PSO ALGORITHM

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Abstract: The integration of distributed generation (DG) units in power distribution networks has become increasingly important in recent years. The aim of the optimal DG placement (ODGP) is For the purpose of improving the voltage profile and power losses reduction, this project proposes a simple and effective approach for power loss reduction (PLR) value is employed for the allocation while the sizing was by using the results from the allocation as local optimum in a modified PSO in order to obtain the global optimum. Load simulations in power flow yielded improvement not only in power loss reduction but also in voltage profile.

This paper proposes a algorithm PSO for optimal power loss reduction in distribution system to minimize the total power loss and improve the voltage profile. The proposed method is tested on a standard 13 bus radial distribution system and simulation results carried out using MATLAB software. The simulation results indicate that PSO method can obtain better results than the simple heuristic search method.

1. Introduction

Distributed generation units (also called decentralized generation, dispersed generation, and embedded generation) are small generating plants connected directly to the distribution network or on the customer site of the meter. In the last decade, the penetration of renewable and nonrenewable distributed generation (DG) resources is increasing worldwide encouraged by national and international policies aiming to increase the share of renewable energy sources and highly efficient micro-combined heat and power units in order to reduce greenhouse gas emissions and alleviate global warming. Next to environmental advantages, DGs contribute in the application of competitive energy policies, diversification of energy resources, reduction of on-peak operating cost, deferral of network upgrades, lower losses and lower transmission and distribution costs, and potential increase of service quality to the end-customer. Moreover, DGs are available in modular units, characterized by ease of finding sites for smaller generators, shorter construction times, and lower capital costs.

Decision about DG placement is taken by their owners and investors, depending on site and primary fuel availability or climatic conditions. Although the installation and exploitation of DGs to solve network problems has been debated in distribution networks, the fact is that, in most cases, the distribution system operator (DSO) has no control or influence about DG location and size below a certain limit. However, DG placement impacts critically the operation of the distribution network. Inappropriate DG placement may increase system losses and network capital and operating costs. On the contrary, optimal DG placement (ODGP) can improve network performance in terms of voltage profile, reduce flows and system losses, and improve power quality and reliability of supply. The DG placement problem has therefore attracted the interest of many research efforts in the last fifteen years, since it can provide DSOs, regulators, and policy makers useful input for the derivation of incentives and regulatory measures.

Therefore, in this paper, PSO method is pro-posed to determine the optimal location of multi-DGs to minimize the total power loss and improve the voltage profile of the distribution systems.

2. Electricity distribution

Electricity distribution is the final stage in the delivery of electricity to end users. A distribution system's network carries electricity from the transmission system and delivers it to consumers. Typically, the network would include medium-voltage (1kV to 72.5kV)[1] power lines, substations and pole-mounted transformers, low-voltage (less than 1 kV) distribution wiring and sometimes meters.

2.1 International differences

In many areas, "delta" three phase service is common. Delta service has no distributed neutral wire and is therefore less expensive. In North America and Latin America, three phase service is often a *Y* (*wye*) in which the neutral is directly connected to the center of the generator rotor. The neutral provides a low-resistance metallic return to the distribution transformer. Wye service is recognizable when a line has four conductors, one of which is lightly insulated. Three-phase wye service is excellent for motors and heavy power use.

Many areas in the world use single-phase 220 V or 230 V residential and light industrial service. In this system, the high voltage distribution network supplies a few substations per area, and the 230 V power from each substation is directly distributed. A live (hot) wire and neutral are connected to the building from one phase of three phase service. Single-phase distribution is used where motor loads are small.

2.2 Distribution network configurations

Distribution networks are typically of two types, radial or interconnected (see spot network). A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is typical of long rural lines with isolated load areas. An interconnected network is generally found in more urban areas and will have multiple connections to other points of supply. These points of connection are normally open but allow various configurations by the operating utility by closing and opening switches. Operation of these switches may be by remote control from a control center or by a lineman. The benefit of the interconnected model is that in the event of a fault or required maintenance a small area of network can be isolated and the remainder kept on supply.

Within these networks there may be a mix of overhead line construction utilizing traditional utility poles and wires and, increasingly, underground construction with cables and indoor or cabinet substations. However, underground distribution is significantly more expensive than overhead construction. In part to reduce this cost, underground power lines are sometimes co-located with other utility lines in what are called common utility ducts. Distribution feeders emanating from a substation are generally controlled by a circuit breaker which will open when a fault is detected. Automatic circuit reclosers may be installed to further segregate the feeder thus minimizing the impact of faults.Long feeders experience voltage drop requiring capacitors or voltage regulators to be installed.

2.3 Distribution industry

Traditionally the electricity industry has been a publicly owned institution but starting in the 1970s nations began the process of deregulation and privatization, leading to electricity markets. A major focus of these was the elimination of the former so called *natural monopoly* of generation, transmission, and distribution. As a consequence, electricity has become more of a commodity. The separation has also led to the development of new terminology to describe the business units (e.g., line company, wires business and network company).Utilities use distribution systems to serve their customers with reliable quality power.

The most common distribution system is a simple radial circuit that can be 100% overhead, 100% underground, or a combination of both. The most common distribution feeder characteristics and classifications are listed below:

1. The distribution voltage classes for most utilities are 5 kV, 15 kV, 25 kV, and 35 kV.
2. Radial distribution lines can be less than a mile to more than 20 miles long. This distance is from the substation to the furthest service point; it is not the total mileage of all branches.
3. A distribution line load can be as high as 1,200 A, but the range of 300–400 A is common.
4. The short-circuit duty at each distribution substation varies depending on transformer size and voltage class, ranging from 10 kA to 50 kA.

3. Load Flow Methods

Many modified versions of the conventional load-flow methods have been suggested for solving power networks with high *R/X* ratio. The following are the effective load flow techniques used in the distribution networks:

- Single-Line Equivalent Method [5]
- Very Fast Decoupled Method [5]
- Ladder Technique [6]
- Power Summation Method [6]
- Backward and Forward Sweeping Method

4. PROPOSED OPTIMIZATION METHOD

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling.

The system is initialized with a population of random solutions and searches for optimization by updating generations. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles. In past several years, PSO has been successfully applied in many research and application areas. It is demonstrated that PSO gets better results in a faster, cheaper way compared with other methods [4].

Particle swarm optimization has been used for approaches that can be used across a wide range of applications, as well as for specific applications focused on a specific requirement. PSO has been successfully applied in areas like function optimization, artificial neural network training, fuzzy system control, and other areas.

4.1 Application of PSO on various fields of Power System Optimization

- ✓ Power system stability design
- ✓ Reactive power and voltage control
- ✓ Dynamic security border identification
- ✓ Non-smooth economic dispatch problem
- ✓ Distribution state estimation

4.2 Main advantages of the PSO algorithm

- ✓ Simple concept
- ✓ Easy implementation
- ✓ Robustness to control parameters
- ✓ Computational efficiency

4.3 PSO Operation

The particle swarm concept originated as a simulation of simplified social system. The original intent was to graphically simulate the choreography of bird of a bird block or fish school. However, it was found that particle swarm model can be used as an optimizer.

PSO simulates the behaviour of bird flocking

- Suppose a group of birds are randomly searching food in an area
- There is only one piece of food in the area being searched
- All the birds do not know where the food is
- But they know how far the food is in each iteration
- So what's the best strategy to find the food?
- The effective one is to follow the bird which is nearest to the food

4.4 Basic PSO technique

Suppose that the search space is D-dimensional Natural creatures sometimes behave as a swarm. One of the main streams of artificial life research is to examine how natural creatures behave as a swarm and reconfigure the swarm models inside a computer. Swarm behavior can be modeled with a few simple rules. A school of fish and a swarm of birds can be modeled with such simple models. Namely, even if the behavior rules of each individual (particle) are simple, the behavior of the swarm can be complicated. Reynolds called this kind of agent as *boid* and tried to generate complicated swarm behavior by computer graphic (CG) animation [16]. He used the following three vectors as simple rules for each particle.

a) to step away from the nearest particle
b) to go toward the destination
c) to go to the center of the swarm

Namely, the behavior of each agent inside the swarm can be modeled with simple vectors. This characteristic is one of the basic concepts of PSO.

- Each member is called ***particle***, and each particle (i^{th} particle) is represented by d-dimensional vector and described as

  $$\mathbf{X_i=[x_{i1},x_{i2},\ldots\ldots,x_{id}].} \qquad \mathbf{5.1}$$

- The set of n particle in the swarm are called ***population*** and described as $\mathbf{pop=[X_1,X_2\ldots X_n].}$ **5.2**
- The best previous position for each particle is called **particle best** and described as

  $$\mathbf{PB_i=[pb_{i1},pb_{i2}\ldots,pb_{id}]} \qquad \mathbf{5.3}$$

- The best position among all of the particle best position achieved so far is called ***global best*** and described as

$GB=[gb_1,gb_2,\ldots,g_{bd}]$. **5.4**

- The rate of position change for each particle is called *particle velocity* and described as

$V_i = [v_{i1}, v_{i2},\ldots, v_{id}]$. **5.5**

- At iteration *k* the *velocity* for *d*-dimension of *i*-particle is

Updated by:

$V_{id}^{k+1} = wv^{k}_{id} + c_1r_1(pb_{id}^{k} - x_{id}^{k}) + c_2r_2(gb_d^{k} - x_{id}^{k})$ **5.6**

The right-hand side (RHS) of equation 5.6 consists of three terms (vectors) like three vectors of *boid*. The first term is the previous velocity of the particle. The second and third terms are used to change the velocity of the particle. Without the second and third terms, the particle will keep on "flying" in the same direction until it hits the boundary. Namely, it is corresponds to a kind of inertia and tries to explore new areas. Therefore, the first term can realize diversification in the search procedure. On the other hand, without the first term, the velocity of the "flying" particle is only determined by using its current position and its best positions in search history.
Where *w* is the inertia weight, c_1 and c_2 are the acceleration constants, and r_1 and r_2 are two random values in range [0, 1].

- The i-particle position is updated by $x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1}$ **5.7**

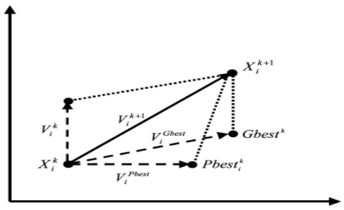

Figure 1:The search mechanism of the Particle Swarm Optimization

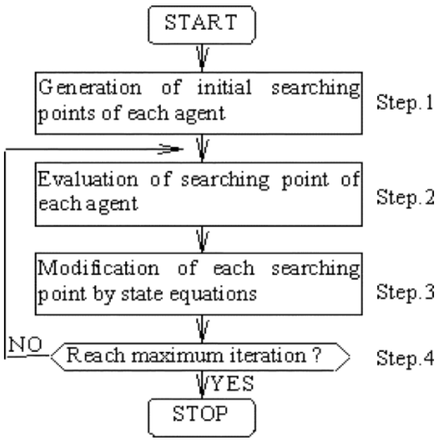

Figure 2 General Flowchart of PSO

4.5 : PSO algorithm

Step 1: (Initialization): Set the iteration number k=0.

Generate randomly n particles, $\{X_i, i=1, 2,\ldots, n\}$,

Where $X^0_i = [x^0_{i1}, x^0_{i2},\ldots, x^0_{id}]$, and their initial

Velocities $V_i = [v^0_{i1}, v^0_{i2},\ldots, v^0_{id}]$.

Evaluate the objective function for each particle $f(X^0_i)$. If the constraints are satisfied, then set the ***particle best*** $PB^0_i = X^0_i$, and set the particle best which give the best objective function among all the particle bests to ***global best*** GB^0.
Else, repeat the initialization.

Step 2: Update iteration counter k=k+1

Step 3: Update velocity using equation (5.6).

Step 4: Update position using equation (5.7).

step 5: Update particle best: **If** $f_i(x_i^k) < f_i(PB_i^{k-1})$ *then* $PB_i^k = X_i^k$

Else $PB_i^k = PB_i^{k-1}$

Step 6: Update global best: $f(GB^k) = \min \{f_i(PB_i^k)\}$

$f(GB^k) < f(GB^{k-1})$ then $GB^k = GB^k$

else $\mathbf{GB^k = GB^{k-1}}$

Step 7: Stopping criterion: If the number of iterations exceeds the maximum numbers allowed, then stop, otherwise go to step 2

4.6 Flowchart for PSO

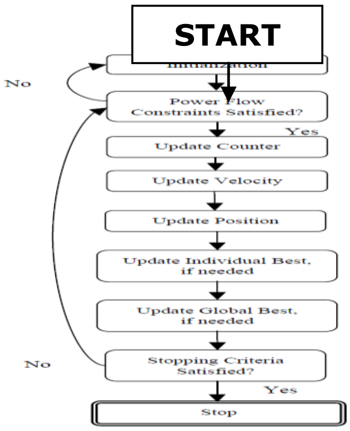

Figure 3 Flowchart for PSO

According to this Project, in the **Particle Swarm Optimization Technique**,

- ✓ The maximum iteration count is set to 100.
- ✓ The acceleration constants c_1 and c_2 are set to 2. (ie., $c_1=2$ & $c_2=2$).
- ✓ The inertia weight is w=1.
- ✓ The total number of particles considered are n=33.
- ✓ The destination is set to 50(D=50).
- ✓ The x_{max} is equal to total power loss (TPL) and the x_{min} is set to zero (where x is the particle position).
- ✓ The objective function f (X_i^0) is the power loss for each particle and the constraints are the voltage limits.
- ✓ In the population of 'n' particles (n=33), the X_i^k is manipulated as the capacitor location.

5. SIMULATION RESULTS

The test system is radial distribution system with 13 buses as shown in Figure 4. The original total real power loss and reactive power and variance of voltage in the system are 336.24 kW, 264.01 kVar and 0.45 pu, respectively. The minimum and maximum voltages are set at 0.95 and 1.05 p.u. respectively. The load data is given in Table1 and branch data in is given Table2. Maximum number of DG is 3. The maximum real power and reactive power of DG are 1200kw and 5kvar, respectively. The improvement in the voltage profile after optimally placing the DGs is shown in Figures 5 and 6. Without DG, the bus 10 has 0.955p.u. and the bus voltage has improved to 0.9576p.u. after installing DG. According to buses voltage profile, in PSO method voltage profile is better improved. Table3 shows the simu-lation results of PSO method for 13 bus systems. For the 13bus system, one DG can reduce the total Power loss and variance of voltage and amount of objective function more than PSO algorithm. For two and three DGs, they can further reduce the total power loss and variance of voltage and amount of objective function more than PSO algorithm

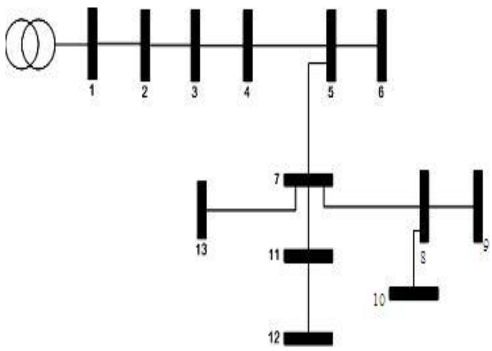

Figure 4 The 13 bus radial distribution system

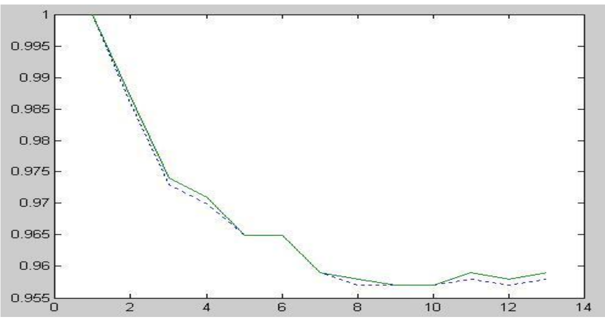

Figure 5 Voltage profile with DG (think line) without DG (dotted line)

Table 1. Load data

BUS	P(KW)	Q(KVAR)
1	0	0
2	890	468
3	628	470
4	1112	764
5	636	378
6	474	344
7	1342	1078
8	920	292
9	766	498
10	662	480
11	690	186

Table 2. Branch data

from	to	R	X
1	2	0.176	0.138
2	3	0.176	0.138
3	4	0.045	0.035
4	5	0.089	0.069
5	6	0.045	0.035
5	7	0.116	0.091
7	8	0.073	0.073
8	9	0.074	0.058
8	10	0.093	0.093
7	11	0.063	0.05
11	12	0.068	0.053
7	13	0.062	0.053

Table 3: P_L,Q_L values with PSO and without PSO

	BUS	P_L(KW)	Q_L(KVAR)
WITH OUT DG	-----	336.24	264.01
PSO	7	295.15	192.95

6. CONCLUSION

This paper presents a thorough description of the state-of the-art models and optimization methods applied to the optimal DG placement (ODGP) in power flow, analyzing and classifying current and future research trends in this field. The most common ODGP model has the following characteristics: 1) installation of multiple DGs; 2) the design variables are the location and size; and 3) the objective is the minimization of the total power loss of the system. The solution methodologies for the ODGP problem are classified into three major categories: analytical, numerical and heuristic methods.

In this paper, a PSO for optimal placement DGs proposed. This method efficiently minimize the total power loss and variance of voltage and amount of objective function and improve the voltage profile satisfying transmission line limits and constraints. The methodology is accurate in determining the sizes and DG locations.

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