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AN OPTIMIZATION APPROACH BASED ON IMPROVED ARTIFICIAL BEE COLONY ALGORITHM FOR LOCATION AND CAPACITY OF GRID-CONNECTED PHOTOVOLTAIC SYSTEMS

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Access of photovoltaic system (PVS) to distribution network impacts voltage and power losses and also other related parameters. In order to make full use of the advantages of PVS and determine its optimal location and capacity, an optimal allocation's method for grid-connected PVS is proposed in this paper. This method takes the active power losses minimization as the optimization goal, divides the distribution feeder system into several paths to determine the path priority to install PVS according to active power load moment (APLM). The allowable maximum and minimum active power of grid-connected PVS for each bus are calculated via voltage sensitivity. The improved artificial bee colony (IABC) algorithm that selects initial solution by using path priority and active power restrictions of grid-connected PVS is applied to achieve the optimal allocation of PVSs. This method was examined with IEEE 33-bus feeder system, and the optimal locations and capacities for different numbers of grid-connected PVSs are determined. The results obtained by the proposed IABC algorithm were compared with the results obtained by the artificial bee colony (ABC) algorithm and particle swarm optimization and those attained via other methods. The results show that the proposed method is feasible and effective. References 11, figures 7, tables 4.

Key words: photovoltaic power, path priority, active power load moment, voltage sensitivity, artificial bee colony algorithm

1. Introduction. With the global depletion of fossil fuels and the worsening of the climate, one of the methods to satisfy the growing power needs of mankind is to generate electricity by using clean energy. In recent years, photovoltaic system (PVS) has been developing rapidly, the related technology is maturing.

However, the connection of PVS to the distribution system changes the power flow, unreasonable access location and capacity of PVS may bring about power losses increasing and voltage violation. So it is of concern to select optimal location and capacity of grid-connected PVS [1, 2]. For the past few years, many research methods have emerged for optimal deployment of the distributed generation (DG) in distribution network. Some researchers divide the optimal problem into two sub-optimization problems including determining the optimal location and optimal capacity of DG-units. In article [3], the novel, combined losses sensitivity, index vector, and voltage sensitivity index methods for optimal location of DG in a distribution network are compared, the optimal DG capacity of the optimal bus location is selected when losses reduction is maximum. It concludes that modified novel method and combined power losses sensitivity are giving overall better results for the test systems. In work [4], the power losses reduction and voltage profile improvement are the goal, and as shown the power rating of DGs should be approximately 2/3 capacity of the incoming generation at approximately 2/3 length of the line, and the proposed approach is tested on IEEE 33-bus and IEEE 69-bus systems. As known, the optimization issues of PVSs' locations and capacities are closely related, if we study these two problems separately, it may result to dense inserting locations that is not sensible. There are many other ways to optimize the deployment of DG, such as intelligent optimization methods which solve the two problems at the same time. In paper [5], the particle swarm optimization (PSO) is used to determine the global optimum capacity of the DG sources at the predicted locations in order to minimize network losses and improve voltage quality. In article [6], the ant colony algorithm is presented for optimal placement and capacity of DGs in radial distribution networks for the purpose of cost minimization. In paper [7], the objective is to minimize total system power losses and improve bus voltage profile, the exponential inertia weight particle swarm optimization (EIPSO) is proposed to determine the optimal location and the capacity of DG, the result showed that the EIPSO is better than artificial immune system (AIS). The above-

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mentioned intelligent optimization algorithms are characterized by a large amount of computation, a long running time of the program, more parameters needed to be set, and slower convergence rate.

In this paper, based on improved artificial bee colony algorithm, a new optimization approach is proposed to determine the optimal PVSs' locations and capacities to minimize active power losses of the distribution network and to improve voltage quality. The path priority and voltage sensitivity are utilized in the improved algorithm. The IEEE 33-bus feeder system is examined. The algorithm is compared with other methods to verify its efficiency.

2. Priority-ordered path. Firstly, the distribution feeder system as shown in Fig. 1 is divided into several paths based on network structure. In Fig.1, the bus number is represented by 1, 2...33, and the branch number is represented by (1), (2), ... (32), so bus k+1 is the ending bus of the branch k. The 33-bus feeder system is divided into four paths, path 1 includes bus 1-2-…-18 , path 2 includes bus 1-2, 19-20-21-22 , path 3 includes bus 1-2-3, 23-24-25, path 4 includes bus 1-2-…6, 26-27-28-…-33 , as shown in Fig. 1 (Path division of IEEE 33-bus feeder system). In order to make the locations of grid-connected PVSs in a heavy load area but not too concentrated, and to reduce effectively the power losses, "a method of active power load moment" is proposed to determine the priority of the path. As known, the active power load moment (APLM) is the product of the active power load and the length of line and the line resistance increases with its length. So, the APLM of per bus is defined as:

$$T_p(i) = R_{di} P_{Li} \quad , \tag{1}$$

where R_{di} is the sum of all branch resistances on the shortest path from bus i to power bus, corresponds to the arm of force; P_{Li} is the active power load at bus i, corresponds to force.

The APLM of the path j equals the sum of the APLM of each bus on the path j,which is defined as:

$$H_j = \sum_{i \in path\ j} T_p(i) \, . \tag{2}$$

The APLM of the distribution network is defined as:

$$H = \sum_{j=1}^{n} H_j \quad , \tag{3}$$

where n is the number of paths, i.e.

H_j is sorted in descending order, and then named as the first level path, the second level ... the j-th level path separately. The priority-ordered paths are used to determine the path priority of grid-connected PVS s' locations. If a single PVS is installed, it will be located at one of the buses in the first level path. If two PVSs are installed, they will be at the buses in the first level path and the second level path, respectively and so on. If H_j is smallest and $H_j < \dfrac{H}{n}$, the j-th level path will not be the candidate path to install PVS.

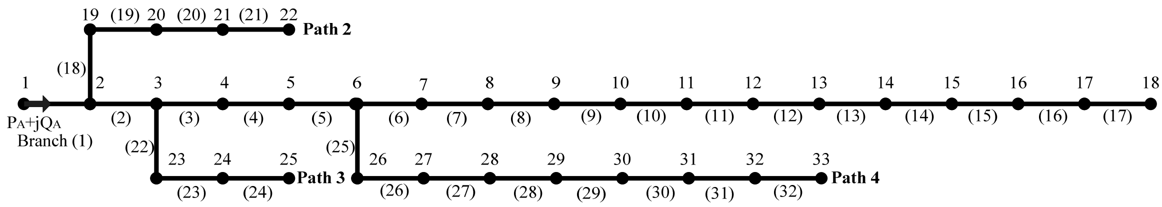

Fig. 1

3. Problem formulation.

3.1. Objective function. The objective function to minimize active power losses in the distribution network is defined as:

$$\min f(X,Y) = P_{loss} = \sum_{k=1}^{F} \frac{P_k^{'2} + Q_k^{'2}}{U_{k+1}^{'2}} R_k \quad , \tag{4}$$

where X=[x1, x2…] are the locations of grid-connected PVSs; Y=[y1, y2…] are the capacities of grid-connected PVSs; P_{loss} are the total active power losses; $P_k^{'}$ and $Q_k^{'}$ are the active and reactive power flow at the end of the branch k after the PVS is installed at bus k+1, respectively. In each branch, the reference direction of power flow is from the bus with a small number to the bus with a large number. U'_{k+1} is the bus voltage of bus k+1 after installation of PVS at bus k+1. R_k is the line resistance connecting bus k and bus k+1(in k-branch), F is the number of branches in the distribution network.

3.2. Constraints.

Since PVS mainly generates active power, power factor of PVS is set to 1 in this paper. So the value of PVS's capacity is equal to the amount of grid-connected PVS's active power. So the "P_{DG}" which is active power of grid-connected PVS is directly used to indicate the capacity of PVS.

$$P_A + \sum P_{DG} - \sum P_L - P_{loss} = 0 \ , \tag{5}$$

$$Q_A - \sum Q_L - Q_{loss} = 0 \ , \tag{6}$$

$$U_{i\min} \le U_i \le U_{i\max} \ , \tag{7}$$

$$\sum P_{DG} \le \sum P_{DG\max} \ , \tag{8}$$

$$P_{DGi\min} \le P_{DGi} \le P_{DGi\max} \ , \tag{9}$$

where P_A and Q_A are the active power and reactive power transmitted from the upper level grid after the PVS is installed in the distribution network, respectively, namely the power flow at the head of branch 1, as shown in Fig.1; $\sum P_L$ and $\sum Q_L$ are total active power load and reactive power load, respectively; Q_{loss} are the total reactive power losses and $Q_{loss} = \sum_{k=1}^{F} \frac{P_k'^2 + Q_k'^2}{U_{k+1}'^2} X_k$, where X_k is the line reactance connecting bus k and bus k+1 (in k-branch); U_i, $U_{i\min}$ and $U_{i\max}$ are the bus voltage, minimum voltage and maximum voltage at bus i, respectively; $\sum P_{DG}$ is the total active power of PVSs that will be installed in the distribution network; $\sum P_{DG\max}$ is the maximum total active power of PVSs that will be installed in the distribution network; P_{DGi} is the active power of PVS that will be installed at bus i in the distribution network; $P_{DGi\max}$ and $P_{DGi\min}$ are the maximum and minimum active power restrictions of PVS that will be installed at bus i in the distribution network, respectively.

3.3. Grid-connected PVS's active power restrictions of each bus. In order to ensure the buses voltage quality when PVSs are installed in the distribution network, the voltage sensitivity [8] is used to calculate the maximum and minimum active power of PVS at each bus. Take the system of Fig. 1 as an example.

The voltage drop in branch k before installing PVS at bus k+1 is as follows:

$$\Delta U_k = U_k - U_{k+1} = \frac{P_k R_k + Q_k X_k}{U_{k+1}} \ . \tag{10}$$

The voltage drop in branch k after installing PVS at bus k+1 is as follows:

$$\Delta U_k' = U_k' - U_{k+1}' = \frac{P_k' R_k + Q_k' X_k}{U_{k+1}'} \ , \tag{11}$$

where U_{k+1} and U'_{k+1} are the bus voltage at bus k+1 before and after installing PVS, respectively; P_k and Q_k are the active power and reactive power at the end (k+1) of the k-branch before installing PVS at the bus k+1, respectively. The voltage drop's deviation of branch k before and after installing PVS at bus k+1 is as follows:

$$\Delta U_k - \Delta U_k' = \Delta(\Delta U_k) = \frac{\partial \Delta U_k}{\partial P_k}\Delta P_k + \frac{\partial \Delta U_k}{\partial Q_k}\Delta Q_k = \frac{R_k}{U_{k+1}}\Delta P_k + \frac{X_k}{U_{k+1}}\Delta Q_k \approx \frac{R_k}{U_{k+1}}\Delta P_k \approx \frac{R_k}{U_{k+1}} P_{DG(k+1)} \ , \tag{12}$$

where ΔP_k is the active power deviation at the end (k+1) of the k-branch before and after installing PVS at bus k+1, approximately equals the value of $P_{DG(k+1)}$; ΔQ_k is the reactive power deviation at the end (k+1) of the k-branch before and after installing PVS at bus k+1, approximately equals 0.

The voltage deviation of bus k+1 before and after installing PVS at bus k+1 is as follows:

$$\delta U_{k+1} = \sum_{i=1}^{k} \Delta(\Delta U_i) = (U_1 - U_{k+1}) - (U_1 - U_{k+1}') = U_{k+1}' - U_{k+1} \approx \sum_{i=1}^{k} \frac{R_i}{U_{i+1}} P_{DG(k+1)} \ , \tag{13}$$

$$S_k = \sum_{i=1}^{k} \frac{R_i}{U_{i+1}}, \qquad P_{DG(k+1)\max} = \frac{\delta U_{(k+1)\max}}{S_k}, \qquad P_{DG(k+1)\min} = \frac{\delta U_{(k+1)\min}}{S_k}, \qquad (14, 15, 16)$$

where S_k is the voltage sensitivity of bus k+1; $\delta U_{(k+1)\max}$ is the difference between the maximum allowable voltage (the maximum allowable voltage of bus 1) and the initial voltage of bus k+1; $\delta U_{(k+1)\min}$ is the difference between the minimum allowable voltage and the initial voltage of bus k+1; the initial voltage of each bus is calculated based on the power flow of the distribution network when no PVS is connected; the maximum and minimum allowable voltage of each bus are determined according to the requirements of different distribution networks for bus voltage.

4. Improved artificial bee colony (IABC) algorithm.

4.1. Artificial bee colony (ABC) algorithm. Artificial bee colony (ABC) algorithm is a metaheuristic optimization algorithm proposed by Karaboga in 2005 to simulate the behavior of the bees when they search for the best food source (solution) [9]. The colony of artificial bees consists of three groups of bees: employed foragers (EF) or employed bees, onlookers, scouts. EF and onlookers each account for half of the total number of bees. EF are responsible for searching for food sources and recruiting bees. In each cycle, EF search for new food source in neighborhood according to

$$V_{ij} = X_{ij} + \alpha(X_{ij} - X_{kj}), i \neq k, \qquad (17)$$

where X_{ij} is the j-th parameter of the solution X_i, V_{ij} is a new solution. The multiplier α is the random number between [–1, 1]. By testing a nectar amount (fitness value), a bee memorizes a new position and forgets the old one if a nectar amount of a new position is higher than the previous one. This behavior is called "greedy-selection". Onlookers are waiting in the dance area of the hive. They watch various dance of the EF, then choose a good source to follow according to the probability value (P_i). P_i is the follow probability of the i-th onlooker calculated as follows:

$$P_i = \left(fitness(i)\right)\left(\sum_{i=1}^{NP} fitness(i)\right)^{-1}, \qquad (18)$$

where $fitness(i)$ is the fitness value of solution i, NP is the total number of food sources (solutions). Then, the onlooker becomes an employed bee to search for the food sources in the neighborhood. If the food source position is tested for over *limited* times and no better solution is found, the EF or onlookers will abandon the current position and turn to be scout bees to avoid exhausting of the food source. The food source that has the best fitness value is the best solution in this cycle. Iterating one by one until the number of iterations reaches *maxCycle*, then the global optimal solution is output [10, 11].

4.2. The optimization method based on the IABC algorithm.

4.2.1. Initialize the populations (solutions) based on the path priority. In ABC algorithm, the initial populations are generated randomly. In order to improve the convergence rate, initial populations are generated according to the path priority and active power restrictions in this paper. The number of food sources (solutions, called Z) is NP. Z=[X,Y], where X is the location variables' vector determined according to aforementioned path priority, X=[$x_1, x_2 ... x_m$], Y is the capacity variables' vector determined by $P_{DGi\max}$ and $P_{DGi\min}$, Y=[$y_1,y_2...y_m$]. Each solution is a D-dimensional vector, $D = 2m$, m is the number of grid-connected PVSs in the distribution network.

4.2.2. Global guidance based cross search mechanism. Although ABC algorithm has a strong neighborhood search capability, the global optimal solution does not participate in the algorithm process, so the algorithm development ability is poor and easily falls into the local optimal solution. This paper refers to the idea of global optimal solution's guidance in particle swarm optimization algorithm (PSO) [5] and the idea of binary crossover in genetic algorithm. After EF searching in the neighborhood, whose new solution is used to cross with the global optimal value to improve the algorithm's development ability, the following expression verifies that:

$$X_{ij}' = \begin{cases} X_{ij} & rand < cr \\ X_j^{Global} + \beta(X_j^{Global} - X_{ij}) & otherwise \end{cases}, \qquad (19)$$

where *rand* is the random value uniformly distributed between 0 and 1, β is the random value between –1 and 1. As shown in article [9], increasing the value of the coefficient *cr* is helpful for enhancing the algorithm's ability to develop and reducing the value of *cr* is advantageous for enhancing the algorithm's searching ability, so *cr* equals 0.6.

During the iteration process, the new solution is guided to the global optimal solution which is helpful to improve the algorithm's searching ability and convergence rate.

4.2.3. Scout bees update strategy. In ABC algorithm, scout bees choosing new food source positions are randomly, so the fitness value of new food source has no advantage than the nectar source that has evolved many times. Consequently, it may cause multiple useless explorations.

In the proposed IABC algorithm, during the scouts searching period of each iteration, firstly, *N* initial solutions are randomly selected from the initial populations, and then PSO algorithm is applied to optimize the *N* solutions. In the PSO algorithm process, the number of iterations is set randomly and the optimal solution of each iteration is stored and sorted, and then the solution with the highest fitness is returned to be the new food source position of the scout bee.

4.3. The solution steps of the IABC algorithm for PVSs' allocation. 1) Initialization. Input the initial information of the network, set the total number of bees (solutions): *NP*, the maximum number of iterations: *maxCycle*, the threshold: *Limit*, food source dimension: *D*, the number of iterations: *inter* = 0. The number of EF is *NP*/2 which equals the number of onlookers. Initialize the food source positions *Z* (solution or population) through the path priority and active power constraints.

2) Calculating the initial optimal solution. Calling the flow program to calculate the fitness of each nectar: *fitness* = *Ploss*, sorting, then determine the current optimal nectar. Initialize flag vector: *trail (i)* = 0 which is used to record the times of bees' staying in the same position.

3) Food source updating. Each employed bee searches for the neighbour solution by using (17), then the solution is used to cross with the global optimal value by using (19) to select a new solution according to the greedy-selection. If the solution doesn't change, change the value of *trail(i)* as follows: *trail(i)*= *trail(i)*+1; each onlooker determines which employed bee to follow by using (18) and then turns to be an employed bee, and then produces a new solution by (17) and crosses with global optimal solution by (19), then selects a better solution by greedy-selection, then updates the value of *trail(i)*. If the value of *trail(i)* reaches *Limit* times, in other words, if the food source doesn't update after being searched for *Limit* times, the employed bee turns to be a scout bee. The scout bee selects a new food source position returned by PSO algorithm as the aforementioned update strategy of scout bees.

4) Record the best food source found by all bees at present; this is the current global optimal solution. Then *inter* = *inter* + 1 and the next iteration is carrying on. If *inter* > *maxCycle*, then stop the calculation and output the global optimal solution; else follow step3).

5. Result and discussion.

The IEEE 33-bus radial distribution system is examined to test the validity of the optimization ideas and algorithms proposed in this paper. The distribution network diagram is shown in Fig. 1. At the head bus of the line in the system, the voltage amplitude is 12.66 kV and the voltage phase is 0. Total active power load is 3715 kW and total reactive power load is 2300 kVar. Total active power losses are equal to 202.688 kW and total reactive power losses are equal to 135.611 kVar.

5.1. Priority-ordered path. According to the priority-ordered path determination method proposed above, the APLM of each path are calculated for determination of path priority. The results are shown in Table 1 (APLM of different paths in IEEE33-bus feeder system). The APLM of the feeder system: *H* = 14017.363. The APLM of the path 2 is smallest and less than *H*/4, so it will not be regarded as the priority path to install PVSs.

Table 1

Path	Buses	APLM	Path priority
1	(1,2,3…18)	6606.13	the first level
2	(1,2,19,20,21,22)	645.097	the fourth level
3	(1,2,3,23,23,24,25)	2156.38	the third level
4	(1,2…6,26,27,28…33)	5056.917	the second level

5.2. Grid-connected PVSs' active power restrictions: $P_{DG\max}$ and $P_{DG\min}$.

$P_{DG\max}$ and $P_{DG\min}$ shown in Fig. 2 (Allowable maximum and minimum active power of PVS for each bus) are the allowable maximum and minimum active power of PVS at each bus calculated by the aforementioned method of voltage sensitivity. The voltage sensitivity of each bus is shown in Fig. 3.

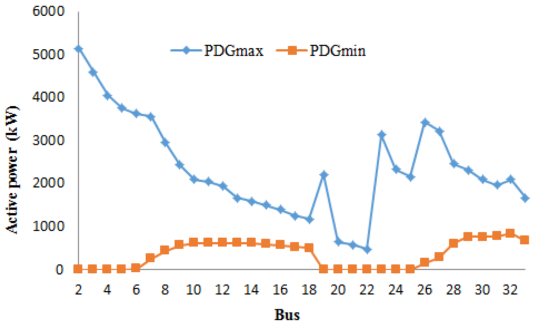

Fig.2

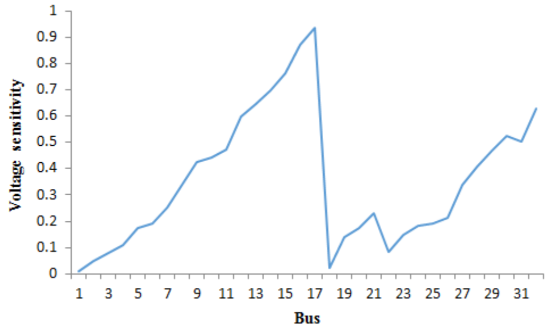

Fig.3

5.3. Optimization results. The PSO algorithm, ABC algorithm and IABC algorithm are utilized in 33-bus feeder system to deploy PVS optimally. Three cases are tested including one, two and three PVSs installed in the 33-bus feeder system. The optimization results of each algorithm are obtained after carrying out 15 independent runs.

5.3.1. Optimal allocation of one grid-connected PVS. The optimization results of PSO, ABC and IABC algorithm are compared with that obtained using other methods [3], shown in Table 2 (Results of optimization by different kinds of algorithm for one grid-connected PVS).

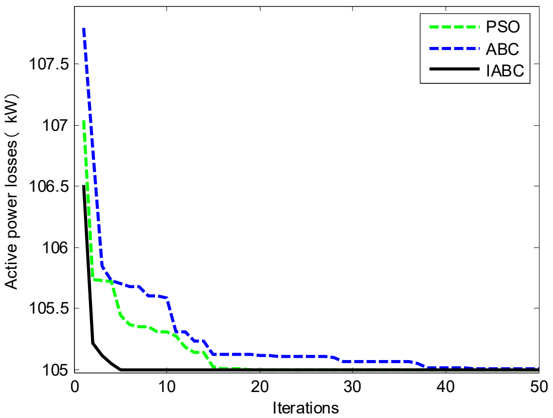

Fig.4

As shown in Table 2, the optimal location of PVS is bus 6 by using the novel method [3] and bus 8 by using the combined power losses sensitivity method [3]. Appling the PSO, ABC and IABC algorithm, the optimal placement of PVS are all at bus 7 (at the end of branch 6). Installing the PVS at bus 7 has larger reactive power losses reduction. Bus 7 is a member of the aforementioned first level path. In contrast, the IABC algorithm has the shortest calculation time and the least number of parameters to be set. As shown in Fig. 4 (Convergence characteristics of different algorithms for one grid-connected PVS), the convergence rate of ABC algorithm is slower than PSO algorithm and the IABC algorithm's convergence rate is fastest.

Table 2

Method	Novel method[3]	Combined power losses sensitivity method[3]	PSO	ABC	IABC
Setting	—	—	N=30; $MaxDT$=50; $c1$=1.4962; $c2$=1.4962; w=0.7298	NP=30; $maxCycle$=50; $Limit$=5;	NP=30; $maxCycle$=50; $Limit$=10;
Optimal location (bus)	6	8	7	7	7
Optimal active power (kW)	2494.8	1800	2441.432	2447.34286	2440.967
Active power losses reduction (kW)	47.32%	44.01%	48.20%	48.20%	48.20%
Time (s)	—	—	15.733	15.8552	13.391

5.3.2 Optimal allocation of two grid-connected PVSs. The optimization results of PSO and IABC algorithm are compared with that obtained using another method [4], shown in Table 3 (Results of optimization by different kinds of algorithms for two grid-connected PVSs).

As shown in Table 3, the optimal positions of PVSs are bus 6 and bus 18 which are in the same level path by using the method [4]. Appling the PSO and IABC algorithm, the optimal placements of PVSs are bus 13 and bus 30 which are in the first level and second level path, respectively. The PVSs' locations in the priority-ordered path that the paper proposed have more active power losses reduction and less calculation time. As shown in Fig. 5 (Convergence characteristics of different algorithms for two grid-connected PVSs), IABC algorithm's convergence rate is faster than for PSO algorithm.

Table 3

Method	[4]	PSO	IABC
Setting	—	*N*=30; *MaxDT*=100; *c1*=1.4962; *c2*=1.4962; *w*=0.7298;	*NP*=30; *maxCycle*=100; *Limit*=5;
Optimal location (bus)	6,18	13,30	13,30
Optimal active power (kW)	2138,495	841.733,1076.572	845.529,1158.053
Total active power (kW)	2633	1918.305	2003.582
Active power losses (kW)	93.49	86.346	85.929
Active power losses' reduction	55.55%	57.40%	57.60%
Time (s)	—	31.289	20.01

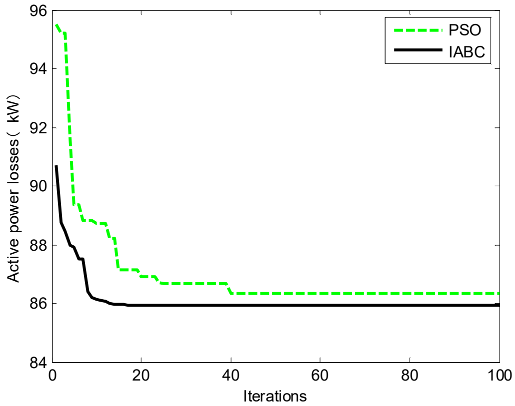

Fig. 5

5.3.3 Optimal allocation of three grid-connected PVSs.

Three PVSs are installed optimally in the system by PSO and IABC algorithm. The results are shown in Table 4 (Results of optimization by different kinds of algorithms for three grid-connected PVSs).

The optimal locations obtained by work [4] are bus 6 (in the first level path), bus 18 (in the first level path), and bus 28 (in the fourth level path). By using PSO and IABC algorithm to deploy three PVSs in distribution network, the locations are bus 14, bus 24 and bus 30 which are in the first level, the second level and the third level path, respectively. The reduction rate of active power losses is 57.08%, 64.66% and 64.74%, respectively. So the proposed IABC algorithm has more active power losses reduction. The run time of IABC algorithm is less than PSO algorithm.

As shown in Fig. 6 (Convergence characteristics of different algorithms for three grid-connected PVSs), IABC algorithm's convergence rate is faster than for PSO algorithm.

Table 4

Method	[4]	PSO	IABC
Setting	—	*c1*=1.4962; *MaxDT*=150; *c2*=1.4962; *w*=0.7298; *N*=30;	*NP*=30; *maxCycle*=150; *Limit*=15;
Optimal location(bus)	6,18,28	14, 24, 30	14, 24, 30
Optimal active power(kW)	1972, 328, 333	788.434, 1078.791, 1046.701	753.971, 1099.173, 1071.329
Total active power(kW)	2633	2913.925	2924.473
Active power losses (kW)	90.24	71.625	71.467
Active power losses reduction	57.08%	64.66%	64.74%
Time(s)		55.23	46.1982

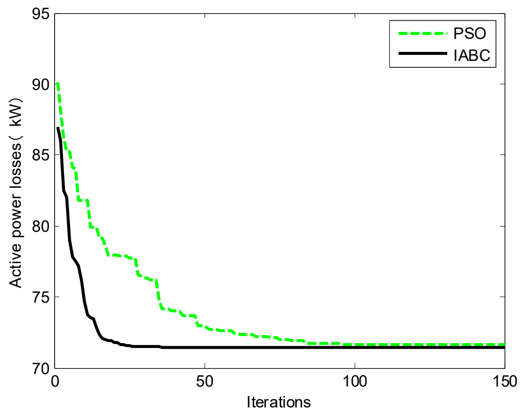

Fig.6

5.4 Voltage profile. Voltage profiles of each bus before and after deploying different numbers of PVSs are shown in Fig. 7 (Bus voltage profile before and after PVSs' deploying). Without PVS installed in the system, voltage of multiple buses are lower than $U_{i\min}$. Nevertheless, after installing PVSs, voltage of each bus increased. Furthermore, with more PVSs installed, the more voltage increased, and no bus voltage is higher than $U_{i\max}$.

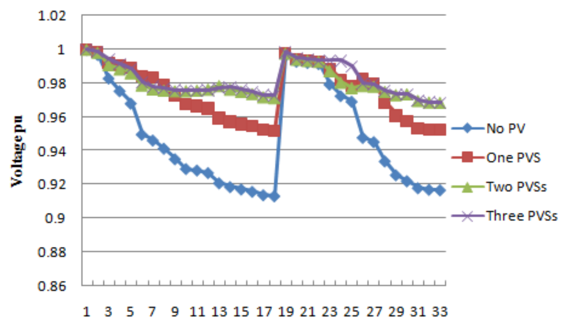

Fig. 7

6. Conclusion

1) This paper presents a new optimization approach to determine the optimal PVSs' locations and capacities to minimize the total system's active power losses and to improve voltage quality. In the approach, an improved artificial bee colony algorithm based on priority-ordered path and voltage sensitivity was proposed. The new approach is validated by the IEEE 33-bus feeder system. The results show that the proposed method cans determine the best location and capacity of PVS, minimize the power losses, improve the voltage quality and speed up the optimization, and the parameter setting is simple and convenient.

2) The objective of this paper is just the active power losses minimization and voltage constraints, that is why only the cases of one PVS, two PVSs and three PVSs installed in the distribution network are considered.

The optimization problems of multi-objective and high density of grid-connected PVSs will be studied in the future by authors.

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ОПТИМИЗАЦИОННЫЙ ПОДХОД НА ОСНОВЕ УЛУЧШЕННОГО ИСКУССТВЕННОГО АЛГОРИТМА КОЛОНИИ ПЧЕЛ ДЛЯ ОПРЕДЕЛЕНИЯ МЕСТОПОЛОЖЕНИЯ И МОЩНОСТИ ПРИСОЕДИНЯЕМЫХ К СЕТИ СИСТЕМ ФОТОВОЛЬТАИКИ

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Использование системы фотоэлектрической генерации (СФГ) в распределительной сети влияет на напряжение и потери мощности, а также на другие связанные параметры. Для того чтобы в полной мере использовать преимущества СФГ и определить ее оптимальное местоположение и мощность, предлагается метод оптимального распределения присоединяемых к сети СФГ. Этот метод в качестве цели оптимизации использует минимизацию потерь активной мощности, разделяет систему распределительных фидеров на несколько путей, чтобы определить приоритетность пути для установки СФГ в соответствии с моментом активной мощности нагрузки (МАМН). Допустимые максимальные и минимальные мощности СФГ для каждой шины рассчитываются, используя чувствительность к напряжению. Усовершенствованный алгоритм искусственной пчелиной колонии (АИПК), который выбирает начальное решение с использованием приоритетности пути и ограничений мощности СФГ, применяется для получения оптимального распределения СФГ. Этот метод был проверен с помощью системы фидеров 33-узловой схемы (IEEE 33-bus), и были определены оптимальные расположение и мощности СФГ для различного количества присоединяемых к сети СФГ. Выполнено сравнение результатов, полученных с помощью предложенного АИПК, оптимизацией роя частиц, а также другими методами. Результаты показывают, что предложенный способ осуществим и эффективен. Библ. 11, рис. 7, табл. 4.

Ключевые слова: фотоэлектрическая мощность, приоритетность пути, момент активной мощности нагрузки, чувствительность к напряжению, алгоритм искусственной пчелиной колонии.

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ОПТИМІЗАЦІЙНИЙ ПІДХІД НА ОСНОВІ ПОЛІПШЕНОГО ШТУЧНОГО АЛГОРИТМА КОЛОНІЇ БДЖІЛ ДЛЯ ВИЗНАЧЕННЯ МІСЦЯ РОЗТАШУВАННЯ І ПОТУЖНОСТІ, ЩО ПІДКЛЮЧАЄТЬСЯ ДО МЕРЕЖІ СИСТЕМ ФОТОВОЛЬТАЇКИ

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Використання системи фотоелектричної генерації (СФГ) в розподільній мережі впливає на напруження і втрати потужності, а також на інші пов'язані параметри. Для того щоб повною мірою використати переваги СФГ і визначити її оптимальне розташування і потужність, пропонується метод оптимального розподілу приєднання до мережі СФГ. Цей метод в якості мети оптимізації використовує мінімізацію втрат активної потужності, розділяє систему розподільних фідерів на декілька шляхів, щоб визначити пріоритетність шляху для установки СФГ відповідно до моменту активної потужності навантаження (МАПН). Допустимі максимальні і мінімальні потужності СФГ для кожної шини розраховуються, використовуючи чутливість до напруги. Вдосконалений алгоритм штучної бджолиної колонії (АШБК), який вибирає початкове рішення з використанням пріоритетності шляху і обмежень потужності СФГ, застосовується для отримання оптимального розподілу СФГ. Цей метод перевірений за допомогою системи фідерів 33-вузловий схеми (IEEE 33-bus), також були визначені оптимальні розташування і потужності СФГ для різної кількості приєднуваних до мережі СФГ. Виконано порівняння результатів, отриманих за допомогою запропонованого АШБК, оптимізації рою частинок, а також інших методів. Результати показують, що запропонований спосіб здійсненний та ефективний. Бібл. 11, рис. 7, табл. 4.

Ключові слова: фотоелектрична потужність, пріоритетність шляху, момент активної потужності навантаження, чутливість до напруги, алгоритм штучної бджолиної колонії.

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