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Analysis of PMU with Distributed Generation and Location with the PSO Algorithm

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Abstract

In recent years, voltage instability has focused on many of its power system users, as well as the growth of demand for electricity and the economy and the environment, has led to the expansion of new energy use. The purpose of this paper was to use a new method for determining the optimal alternative and the minimum number of PMU units in the network based on the best PSO algorithm. From the perspective of the PMUs in the system, location optimization is performed based on the mode of estimation for variable voltage and control variables in a distribution network with DG resources and multiple loads. The purpose of this research is to determine the optimal alternative and the minimum number of units of the PMU and the difference in voltage voltages in the network based on the algorithm.

Keywords: **PMU**, **Distributed Generation**, **PSO Algorithm**

1. Introduction

In recent years, due to the increase of distributed energy sources and the importance of distribution networks, as well as the reduction of losses and increased reliability, and as a result of increasing the quality of the power supply to consumers, several studies have been conducted to estimate the state of the electrical energy distribution systems with the presence of distributed generation sources, as well as The use of voltage control equipment has been made, including the following:

In reference [1], an analysis of the estimation of the state of the Italian electricity distribution system based on the least squared weighting method with regard to the problem of the robustness of the estimation results and the effect of the accurate evaluation of the results of the estimation of the distribution system state on the method of optimizing the optimal measurement location based on the rule has been investigated. The results show that the use of an optimal and additional measurement system according to the proposed method can significantly reduce the risk of decision-making that results from inaccurate information from the estimated values, and in general can be able to derive an estimate of the system of distributed distribution system in Consider the low accuracy of the measuring device. Pig gate and colleagues presented [2] a new PMU based on an error detection method and its location for active distribution networks using real-time estimation. Test validation is performed on a real 18-basset distribution network, which is located on each buss of a PMU. The proposed method identifies the error line, regardless of the natural connection, the type of error, impedance, and error location along the line, and is also significantly resistant to noise.

In order to evaluate the amplitude and angle of the phase voltage of the three phases and the non-equilibrium indices taking into account different types of measurements, in [3], the real-life and three-phase imaginary voltage estimator was used and tested on the IEEE standard 13-pin system and the resulting information The measurement of the branch indicates that the proposed method is accurate to the values.

A new orbital representation model of state estimation errors in distribution networks is presented in [4]. In this method, state estimation errors are modeled as ground resistivity of an orbital scheme of interest matrices. The effects of branch and knot measurements on state estimation are described by the elements of the circuit. Voltage measurements are modeled in the form of parallel admittances and current and power measurements are considered as branching admittance. The results of this study show that using this method; a general optimization can be obtained for optimizing the position optimization problem based on the integer linear programming (MILP) problem .A control framework for supporting voltage and reactive power by a reactive power supply injection source is provided at the distribution network level in [5]. First, a nonlinear dynamic input is formulated for the state model, and then a KALMAN filter is designed based on the dynamic mode estimation method. Using the simulation of a radial distribution network and considering the effect of telecommunication noise, the proposed method has been analyzed and analyzed .Reference [6] provides a robust algorithm for estimating the threefold distribution of distributed networks. To reduce the complexity of the calculations, the matrix Jacobin has been considered as a constant, and this is done by converting the voltage phase of the node and converting the equivalent of the amplitude of the current, and then implemented with numerical examples of the algorithm. The results show that the proposed method is a stable and stable method .The importance of estimating the distribution state is shown in [7] if different measurements, which include real measurements and unrealistic measurements. In this paper, two different estimators of Post and Huber are presented and simulated on a real mean voltage feeder. Both methods show that improvements in the results from the estimation of the voltage range in both methods have been achieved when the sensor has a 5% voltage error measurement.

In [8], a modeling framework for analyzing the privacy of customers equipped with smart metering in a radial distribution network is presented. Several different state-of-the-art estimates schemes have been proposed, and then there has been a mix between the operator's profits and the customer's private casualties. The results show that the measurements collected from small customers can improve the operator's estimation to reduce private sector losses .In [9], proposed a state-of-the-art estimation based on the weighted least squares algorithm and limited point’s voltage and used the Newton-Rap son method to solve the model. The results show that the proposed model can estimate the state of all points with limited measurements and in different load conditions with lower error than actual values .A method for estimating the current flow of branches by considering transformers and voltage regulators in a distribution network of 20,000 nodes is presented in [10]. Considering the fact that the location of the Trans-Tape also has an important effect on the accuracy of the state estimation, it is estimated that the locations of the tuples are reduced by reducing the location of the tuple using the proposed method. The baseline voltages of 120V are shown for the standard deviations, minimum errors, and maximum voltage errors in a table .Therefore, considering that a large part of the losses are related to the distribution system, it is very important to reduce the losses in this sector. On the other hand, with the optimal estimation of the state of the distribution systems, the quality of the delivered electricity to the consumers can be increased and the reliability of the system Picked up In addition, due to the expansion of the use of distributed generation sources and, of course, due to the reduction of environmental pollution that results in the use of renewable energy sources in dispersed products, the assessment and estimation of voltages and powers in the distribution system will become more important in these circumstances. Due to the oscillating nature of some new energy sources such as wind, problem solving will be more complicated and the use of statistical and probabilistic methods in solving is very effective. In general, due to the expansion of the use of new energy sources and the reduction of losses and increase the reliability of the network and thus the improvement of the stability of the power system, it is tried to optimize the problem of the state of the distribution system, taking into account the above conditions, and The results are used to increase the stability and reliability of the power system, especially the distribution system, as well as to reduce losses and increase efficiency.

2. Formulation of the problem

Power system state estimation procedure aims to estimate the state vector x of the system which includes the voltage of bus and angles by using the available real-time monitoring. The measurement set consists of magnitude of bus voltage, real and reactive power currents, and real and reactive bus booster powers. The PMU can provide voltage magnitudes and their angles directly if it would be more affordable. The principle formula for state estimation solution is as follows (1).The objective function is the summation of difference between the measured and calculated values. The equality and inequality constraints are defined in DSE to create the real time safe and secure operating conditions for devices which are connected to the distribution network. Mathematical formulation of DSE with regard to variable loads and distributed generations as state variables in this paper can be implemented, as following expressions (1), (2), (3), (4), (5), (6), (7), and (8) [11] , So to be produced every the maximum and minimum limits for P, V, Q.

$$\mathrm{Min} \sum_{i=1}^{MD} Wi(\mathrm{Zi} - \mathrm{hi(x)})^2 \tag{1}$$

$$P_{DGi-min} \le P_{DGi} \le P_{DGi-max} \qquad DGi = 1,2,\dots,nDG \tag{2}$$

$$P_{VLoad\,i-min} \le P_{VLoad\,i} \le P_{VLoad\,i-max} \qquad VLoadi = 1,2,\dots,nvl \tag{3}$$

$$V_{b\,i-min} \le V_{b\,i} \le V_{b\,i-max} \qquad bi = 1,2,\dots,nb \tag{4}$$

$$0 \le Q_{c\,i} \le Q_{c\,i-max} \qquad ci = 1,2,\dots,nc \tag{5}$$

$$T_{api-min} \le T_{api} \le T_{api-max} \qquad Tapi = 1,2,\dots,nt \tag{6}$$

$$\left|P_{line\,ij}\right| \le P_{line\,ij-max} \tag{7}$$

$$X = [V_{b1}, V_{b2}, V_{b3}, \dots, V_{bn}] \tag{8}$$

3. PSO Algorithm

PSO algorithm is based on a quick search provides a seal method. PSO algorithm particles are in the same place relative to the time change. PSO particle in the search space to move around during the movement of the particles only according to the position the amount $pbest$ called his position with regard to neighboring particles, which is also called $gbest$ the best of their position [12].

$$\boldsymbol{Vik+1 = wVik + c1\, rand1}(\ldots)\ \boldsymbol{x}\ (\boldsymbol{pbesti - sik}) + \boldsymbol{c2\, rand2}(\ldots)\ \boldsymbol{x}\ (\boldsymbol{gbest - sik})\ \ldots.. \quad \textbf{(9)}$$

$vik:\ velocity\ of\ agent\ i\ at\ iteration\ k,$

$w: weighting\ function$

$cj:\ weighting\ factor, random\ number\ between\ 0\ and\ 1,$

$sik:\ current\ position\ of\ agent\ i\ at\ iteration\ k,$

$pbesti:\ pbest\ of\ agent\ i,$

$gbest: gbest\ of\ the\ group$

$$\boldsymbol{w = wMax} - [(\boldsymbol{wMax - wMin})\ \boldsymbol{x\ iter}]/\boldsymbol{maxIter} \quad (10)$$

$where\ \ wMax = initial\ weight,$

$wMin = final\ weight,$

$maxIter = maximum\ iteration\ number,$

$iter = current\ iteration\ number.$

$$\boldsymbol{sik+1 = sik + Vik+1} \quad (11)$$

After iteration, speed and position of a particle is update. PSO algorithm flowchart And PSO Figure (1) and (2) shown [13].

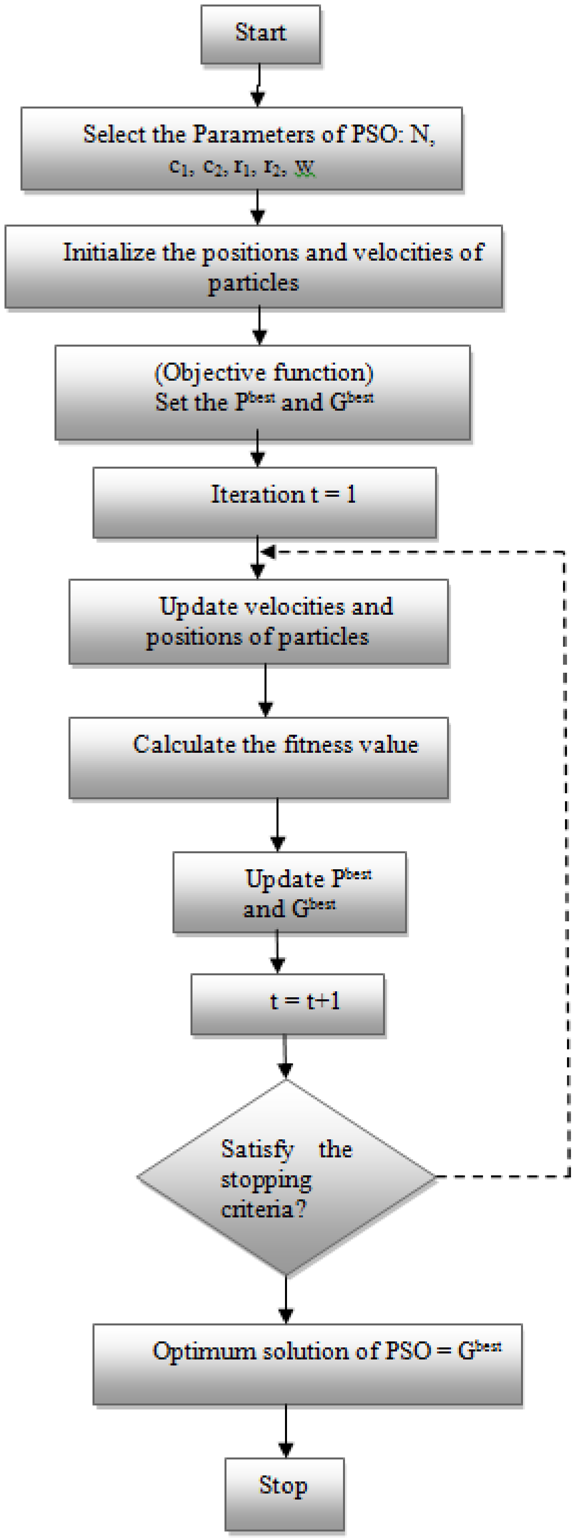

Figure 1- PSO algorithm flowchart

4. Case studied

The proposed method is applied to a test system shown in Figure 2. The values of loads are given in Table (1). The network has 30 buses, accurate data is available on the capacity of active and non-active loads requested, and the apparent capacity of the branches is rescued from the resistance and response of each line in one piece of the original reference [11].

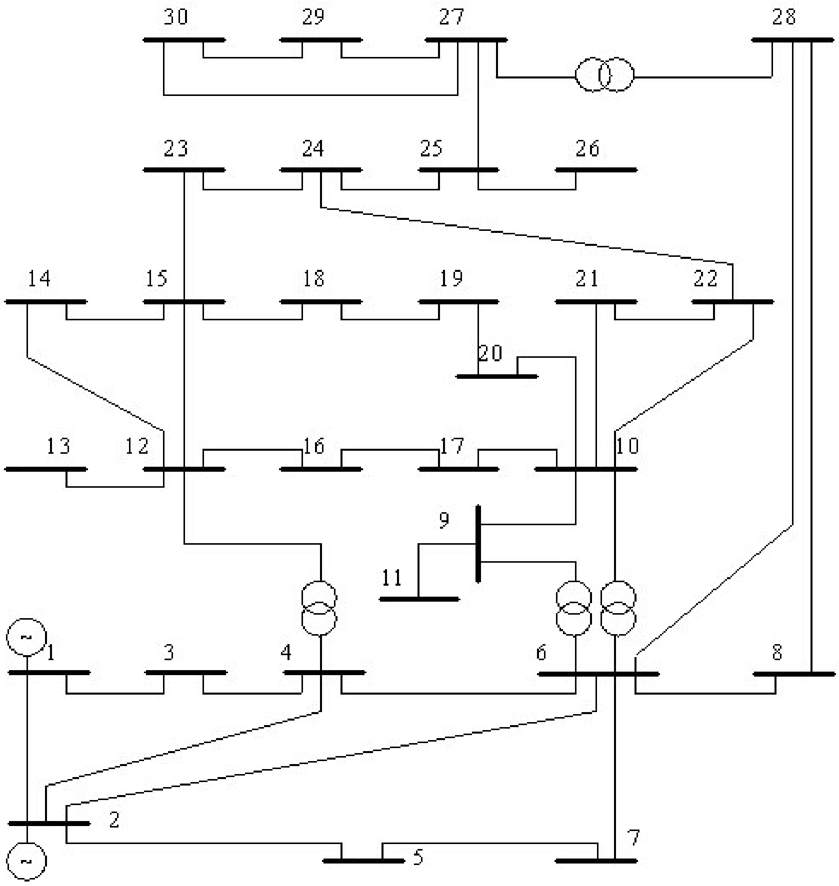

Figure 2- The one-line diagram of 30-bus radial test

DGs products are energy sources that are often connected to the network at near-average frequency centers that are connected to a moderate voltage so that they can be influenced by the customer's trustworthiness and power. In general, dispersed products to the existing field or function can be as Wind turbine and solar system are used in the study of the network. It is assumed that the average voltage distribution of 20 kV from the broadcast network is carried out under balanced conditions, and that the DG model is in the 2nd row. Table 2 shows the information of this model.

Table 1- Location and size range for distributed products

Bus location	Power Active (MW)	Power Reactive (MVAR)
2	40	21.7

5. Simulation results using PSO algorithm

The PSO algorithm is used to optimize the number of PMUs in the wider network. In this research, it is suggested for the optimal substitution and number of PMUs. Given the conditions for the visibility of PMUs and according to the problem formulation, the best places to put the PMUs are as high as possible for system visibility Determined. In this section, two experiments are carried out in the first experiment of the location of the PMU with the PSO algorithm. The results are presented in Table (2). The required data are used to estimate the state of the algorithms, and the voltage matrix and power of the lines and power of the bases observed by the PMUs are extracted and then by placing the PMU number, the locations Different voltage estimates are combined. In the first experiment, we consider 11 PMUs, which, using the PSO algorithm, show the results of convergence shown in Figure 3, the location of the PMUs in the power network is determined. In the PSO algorithm, in the first step, network information is defined including branch impedance, as well as DG power factor and variable loads .In the second step, the selected bases that are installed on the PMU are created. The density is assumed to be the same for each particle. In step three there is a process that determines the next position of each particle. Therefore, the particles in the PSO must be aligned in the direction and direction Specific motion. It is determined by the combination of the best local position. If position convergence is acceptable for solving the DSE problem by the PSO method, then the output of this step will be sent to the next step of the algorithm as the input data to start the local search. Alternatively, the process should be repeated in step 3. In the end, if the convergence is prepared for the DSE problem, the algorithm is finished and outputs that contain the network buss are created.For 11 PMUs and their placement in the 30 Bass Network, respectively, 1-3-6-8-9-11-14-18-21-25-30 respectively. Therefore, the PMU substitutions on the particular buss in the network should be selected, so the probability of viewing the entire network is provided by a number of PMUs used.   In Figure 4, the convergence of the PSO algorithm is shown for the 16 PMUs.

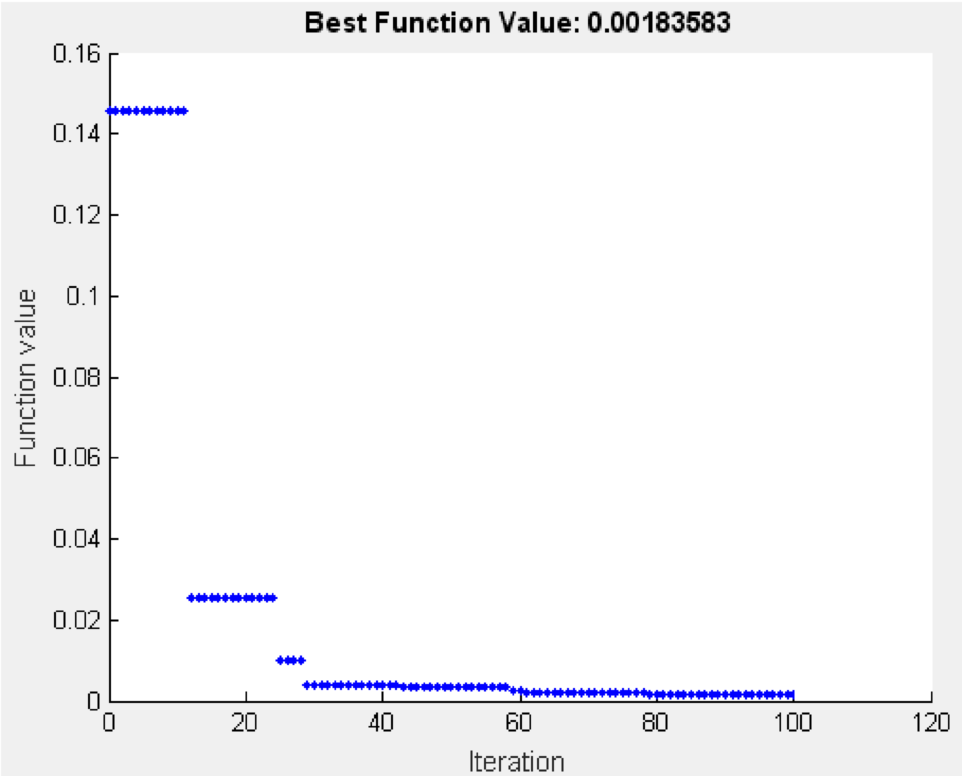

Figure 3- The path of convergence of the PSO algorithm for 11 PMUs

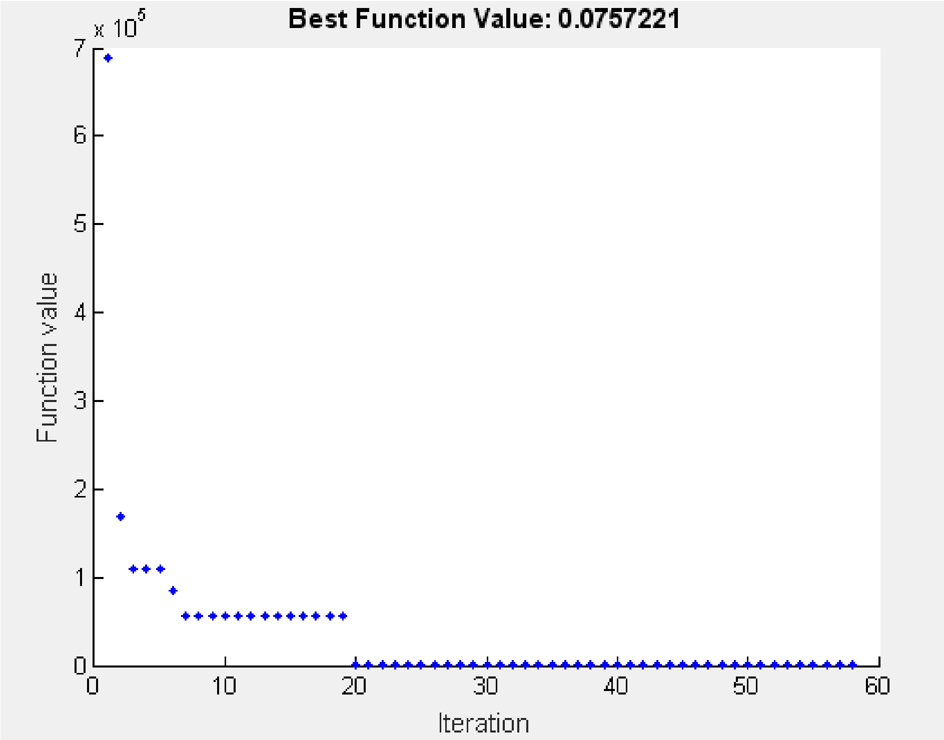

Figure 4- The path of convergence of the PSO algorithm for 16 PMUs

For 16 PMUs, their location in the 30-bus network will be 2-3-4-7-9-11-14-15-17-18-19-20-21-24-25-30 respectively. In the table the results obtained from the PSO algorithm are summarized.

Table 2- Results obtained for PMU location using the PSO algorithm

Operating Conditions	Number of PMUs	The location of the PMUs in the network
	11	1-3-6-8-9-11-14-18-21-25-30
	16	2-3-4-7-9-11-14-15-17-18-19-20-21-24-25-30

The pharos voltage can be estimated in each bus by the minimum difference between actual values and measured values after the placement of PMUs with dispersed products. Table 3 illustrates these results.

Table 3- Basel voltage before the PMU is placed after placing the PMUs and DG

Buses	and DG Bus voltages before placement of PMUs	Bus voltages after placement of PMUs and DG
1	1.06	1.0600
2	1.043	1.0330
3	1	1.0135
4	1.06	1.0028
5	1.01	1.0000
6	1	1.0005
7	1	0.9924
8	1.01	1.0000
9	1	1.0305
10	1	1.0138
11	1.082	1.0720
12	1	1.0451
13	1.071	1.0710
14	1	1.0269
15	1	1.0194

16	1	1.0245
17	1	1.0116
18	1	1.0049
19	1	0.9996
20	1	1.0024
21	1	1.0008
22	1	1.0041
23	1	1.0012
24	1	0.9911
25	1	0.9945
26	1	0.9764
27	1	1.0053
28	1	0.9985
29	1	0.9851
30	1	0.9734

6. Conclusion

The optimal PMUs placement problem is a multidimensional and multi-functional problem because PMUs can be installed for many objectives. Therefore, this paper has focused on the main objectives of PMU employment rather than the methods of finding the optimal placement, which the previous studies have focused on. What is important from this research point of view is to know the main requirements and the possible constraints of PMU employment and hence. For the number of PMUs, the optimal position of the studied system for this purpose was checked for PMUs 11 and 16 at optimal positions of 30 bass feed lines with the PSO algorithm. According to our expectations of the picture, it can be concluded that the difference between the measured voltage and the 30-buses resonated with the PMU in the optimal network position will be changed, Effective process for the optimal replacement of the PMU based on the error estimate. The constant variable provided by the proposed method the algorithms used to solve the DSE problem in the presence of DG can be a good alternative, and the number of PMUs in different bots from the distribution grid is determined in a real time system. The simulation results showed that it is accurate.

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