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Optimal Placement of Multiple Distributed Generation to Improve Voltage Stability as well as Minimize Loss in Distribution System

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Abstract:*Theaim of paper is to presents a technique based on Particle Swarm Optimization (PSO) to identify the switching operation plan for feeder reconfiguration and optimum size value of DG simultaneously. The key purpose is to diminish the real and reactive power losses and improve the bus voltage profile in the system while satisfying all the distribution constraints. A method based on PSO algorithm to find out the minimum formation is presented and their impact on the network real power losses and voltage profiles are investigated. The results are obtained through MATLAB coding.*

Keywords:*Radial Distribution System,Particle Swarm Optimization (PSO), Distributed Generation (DG), loss reduction and MATLAB.*

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I. Introduction

The growing demand in the power system has posed a challenging task to power system engineers in maintaining areliable and safe system cheaply. In the heavily loaded network, the load current drawn from thesource would raise. Thismay lead to an increase in voltage drop and system losses. The performance of distribution system becomes inefficientdue to the reduction in voltage magnitude and increase in distribution losses. Therefore, the operating cost will alsoincrease. With this regard, changing environment of power systems design and operation have necessitated the need toconsider active distribution network by incorporating Distributed Generation units (DGs) sources [18]. The incorporation ofDGs in distribution system would prime to improving the voltage profile, reliability improvement such as service,refurbishment and uninterruptible power supply and increase energy efficiency.The distribution feeder reconfiguration(DFR) is one of the largely significant control arrangements in the distribution networks, which can be affected by theinterconnection of DGs.Generally, the DFR is defined as varying the topological structure of distribution feeders bychanging the open/closed status of section and tie switches so that the power losses is minimized, and theconstraints are met. The analysis from [1] has suggested of employing a method based on heuristic algorithm todetermine the configuration of radial distribution networks, which finally led to loss minimization. Mohammadiet al. [19] also described heuristic optimization technique for the reconfiguration of distribution networks to decrease theirresistive line losses. In another approach, Lopezet. al. [2] proposed a solution procedure by employing simulated annealing (SA) to search a satisfactory non-inferior solution. In [20], Sawa has proposed the new method in networkreconfiguration that involves the discrete decimal mutant PSO and the fixed loop method. Jin et al [21] introduced a binaryparticle swam optimization based reconfiguration methodology for the distribution system. The purpose of theirconfiguration was load balancing. The reconfiguration methodology proposed in that work can only be applied in thepower system with radial configuration. Zhou, et al [4] put forward a heuristic reconfiguration methodology for thedistribution system to decrease the operating cost in a real time operation environment. In that work, the operation cost inthe power system is the power loss in the distribution system. The operation cost reduction in that work is based on thelong term operation of the power system. Another heuristic search based reconfiguration algorithm was proposed by Wuet al [3]. In that work, the reconfiguration methodology was apply to the radial power system for service restoration, loadbalancing, and repairs of the power system.

This paper proposes anetwork reconfiguration method for distribution network connected with DGs using the PSO algorithm. The proposedmethod is able to produce an optimum configuration in network distribution and at the same time yield the optimal sizeof DG and decrease power loss. The proposed PSO also improves convergence characteristics and less computation timeas compared with GA technique. The effectiveness of the methodology is demonstrated by a practical sized distributionsystem consisting of 33-bus system. The fine points of these algorithms are discussed in section II. Meanwhile, SectionIII shows the performance of this algorithm using standard test function. The results in terms of voltageprofile and power loss are discussed in Section IV and finally the last section grants the conclusion of the study.

II. Problem Formulation

The purpose of distribution network reconfiguration is to find a radial operating structure that minimize the system powerlosses while fulfilling operating constraints. Thus the problem can be formulated as follows [21].

$$Min\ P_{Loss} = \sum_{i=1}^{n} |I_i|^2 k_i R_i^{iN} \quad (1)$$

Where is I_i = current in branch *i*, R_i = resistance of branch *i*, *N* is the total number of branches and k_i is thevariable thatrepresents the topology status of the branches (1=close, 0= open).

Subject to:

a) Radial network constraint: Distribution network should be composed of radial structure considering operational point view.

b) Node voltage constraint: Voltage magnitude Vi at each node must lie within their permissible ranges to maintainpower quality

$$v_{\min} \le v_{bus} \le v_{\max} \quad (2)$$

The standard minimum voltage used is 0.95 and maximum voltage is 1.05 (±5%). The process of works begins withthe initial population.

c) Generator operation constraints: All DG units are only permitted to operate within the acceptable limit where $P_i^{\min}$ and $P_i^{\max}$ are the lower and upper bound of DG output.

$$P_i^{\min} \le P_g \le P_i^{\max} \quad (3)$$

d) Feeder capability limits:

$$|I_k| \le I_k^{\max} \quad k \in \{1, 2, 3, ...l\} \quad (4)$$

where $I_k^{\max}$ = maximum current capability of branch *k*.

III. Fundamental Particle Swarm Optimization Algorithm (PSO)

The basic idea of the PSO is based on the social behavior (foraging) of organisms such as fish (schooling) andbird(flocking) [16-17]. The birds or fish will move to the food in certain speed or position. Their movement will depend ontheir own experience and experience from other 'friends' in the group (P_{best} and G_{best}).

The new velocity, V_j^{k+1} and the new position, X_j^{k+1} for the fish or birds are obtained using Eq.(5) and (6).

$$V_j^{k+1} = \omega \times V_j^k + C_1 \times rand_1 \times \left(P_{bestj}^k - X_j^k\right) + C_2 \times rand_2 \times \left(G_{bestj}^k - X_j^k\right) \quad (5)$$

$$X_j^{k+1} = X_j^k + V_j^{k+1} \quad (6)$$

where V_j^k is the velocity of particle *j* in iteration *k*, X_j^k is the position of particle *j* in iteration *k*, $rand_1$ and $rand_2$ are therandom numbers between 0 and 1. P_{bestj}^k is the finest value of the fitness function that has been achieved by particle *j*before iteration *k*. G_{best}^k is the best value of the fitness function that has been achieved so far by anyparticle. Constants $C_1$and C_2 are weighting factors of the random acceleration terms which are usually set to 2.0. While small values allowparticles to move away from the target region before they are pulled back, high values result in sharp movements towardthe target region. The inertia weight ω is typically set according to the following equation:

$$\omega(t+1) = \omega_{\max} - \frac{\omega_{\max} - \omega_{\min}}{t_{\max}} \times t \quad (7)$$

In Eq.(7), $t_{\max}$ is the maximum number of iterations and t is the current iteration number. $\omega_{\max}$ and $\omega_{\min}$ aremaximumand minimum of the inertia weights, respectively. The process of implementation of PSO algorithm is as follows:

In this work, we only determined the optimal size of DG while the location of DG is fixed [12]. DG location in thenetwork is fixed as a controlled measure in order to observe the responding changes of DG sizing. Furthermore, the DGlocation in practical is also depends on the suitability of the area.

Step 1: The input data including network configuration, line impedance and status of DGs and switches are to be read.

Step 2: Setup the set of parameters of PSO such as, number of particles *N*, weighting factors and C_1, C_2. The initialpopulation is determined by selecting the tie switches and DG size randomly from the set of the original population. Thevariable for tie switches represented by *S* and as for DG size is represented by P_g . The proposed particles can be writtenas:

$$X_{particle} = \left\{ S_1, S_2, ...S_\beta, P_{g1}, P_{g2}, ...P_{g\alpha} \right\} \quad (8)$$

Whereβ is the number of tie line and α is the number of DG.

Step 3: Calculate the power loss using distribution load flow based on the Newton - Raphson method.

Step 4: Randomly generates an initial population (array) of particles with random positions and velocities on dimensionin the solution space.Set iteration counter $k=0$.

Step 5: For each particle if the bus voltage is within the limits, calculate the total loss using distribution load flow.Otherwise, that particle is infeasible.

Step 6: Record and update the best values. The two best values are recorded in the searching process. Each particlekeeps track of its coordinate in the solution space that is associated with the best solution it has reached so far. This valueis recorded as P_{best} . Another best value to be recorded is G_{best} ,which is the overall best value obtained so far by anyparticle. P_{best} and G_{best} are the generations of switches, Dg sizes and power loss. This step also updates P_{best} and G_{best} . Atfirst, we compare the fitness of each particle with its P_{best} . If the current solution is better than its P_{best} , then replace P_{best} by the current solution then, the fitness of all particles is compared with G_{best} . If the fitness of any particle is betterthan G_{best} , then replace G_{best} .

Step 7: Update the velocity and position of the particles. Eq.(5) is applied to update the velocity of the particles.Thevelocity of a particle represents a movement of the switches. Meanwhile, Eq.(6) is applied to update the position of theparticles.

Step 8: End conditions.
Check the end condition, if it is reached the algorithm stops, otherwise, repeat steps 3-7 until the end conditions aresatisfied.In this workwe only determine the optimal size of DG while the location of DG is fixed [12].DG location in thenetwork is fixed as a controlled measure in order to observe the responding changes of DG sizing.Furthermore,the DGlocation in practical is also depends on the suitability of the area.

IV. Case Studies

The test system for the case study consisting of the standard IEEE 33 bus radial distribution system is shown infig(1).The system consists of one feeder, 32 normally closed tie line and five normally open tie lines (dotted line) andlocated on branch No. 33, 34, 35, 36 and 37. The system load is assumed to be constant and S_{base} = 10.0MVA andV_{base} = 12.66KV. The line and load data details can be referred in [14]. The total load on the system is 3715kW and2300kVAr. The maximum active output of DG in this study is set to 5MW. While, the size of the population for testsystems is 50.The convergence value is take n as 0.0001. The minimum and maximum voltages are set at 0.95 and1.05p.u.respectively.All calculations for this method are carried out in the per-unit system. Four cases are considered:
Case 1: The system is without distributed generation and feeder reconfiguration (initial)
Case 2: The same as case 1 except that the feeders can be reconfigured by the available sectionalizing switched and thetie switches.
Case 3: The same as case 1 except that there is, two DGs unit is installed and placed at bus number 12 and 28 respectivelywith feeder configuration.

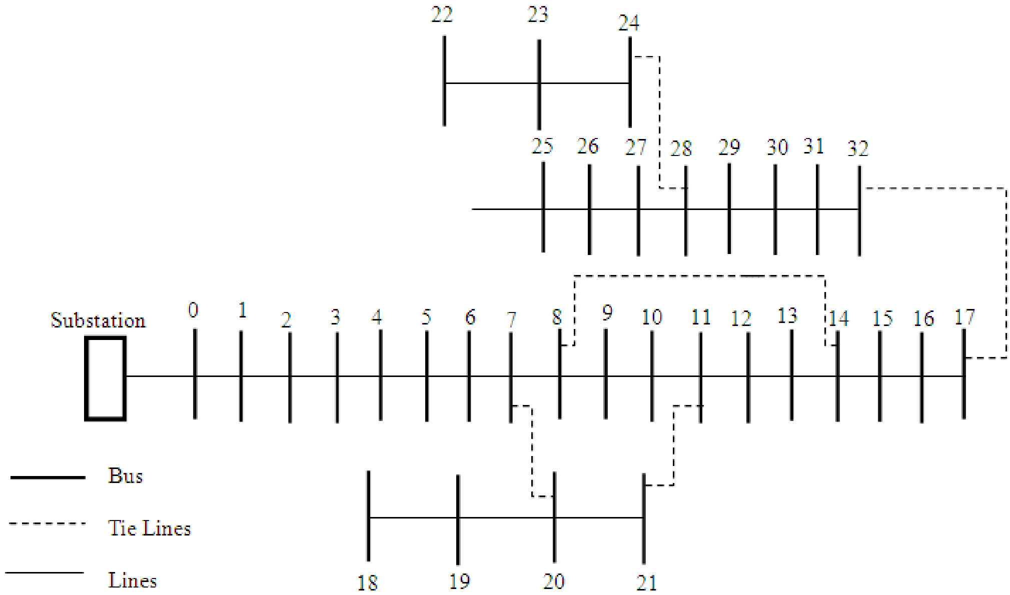


Figure 1: Initial Configuration of the 33 bus radial distribution system

V. Results And Discussion

Table – 1: The Size, Locations and Power Loss Reduction of 33-Bus System

Parameters	**Ploss – No DG (kW)**	**Ploss – One DG (kW)**	**Ploss – Two DG (kW)**
TotalSystemActivePower Loss	202.71	128.50	89.50
ActivePower LossReduction(%)	---------	36.61	55.84
OptimalLocations	---------	12	28
DG-size(kw)	---------	36.14 – (12)	36.14 – (12) 88.60 – (28)

V.1 Impact on Power Losses

After this algorithms is executed by using MATLAB software, only the minimum power loss with optimalDG size is selected.The results obtained consists of the total power loss and two optimal DGsizing. The numerical results for the four cases are summarized in Table 1. The results show the performance of PSOwhen tested using 33-bus distribution system. It is noticed a considerable decrease in the power loss values when the DGis placed in the distribution system. It is confirmed from case 3 that the DG and feeder configurationhelps to reduce the power loss afterreconfiguration from 202.70 kW to 89.50 kW, or 55.84% of the reconfigurations withDG installation.

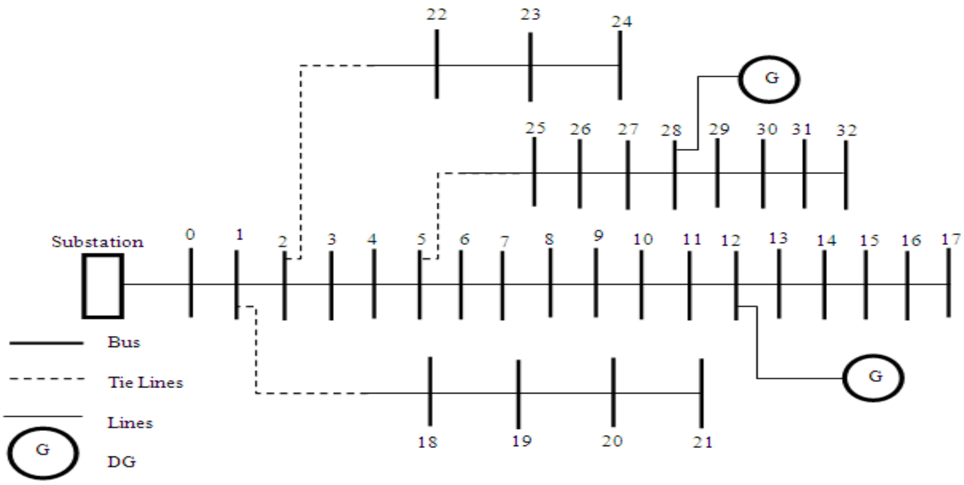
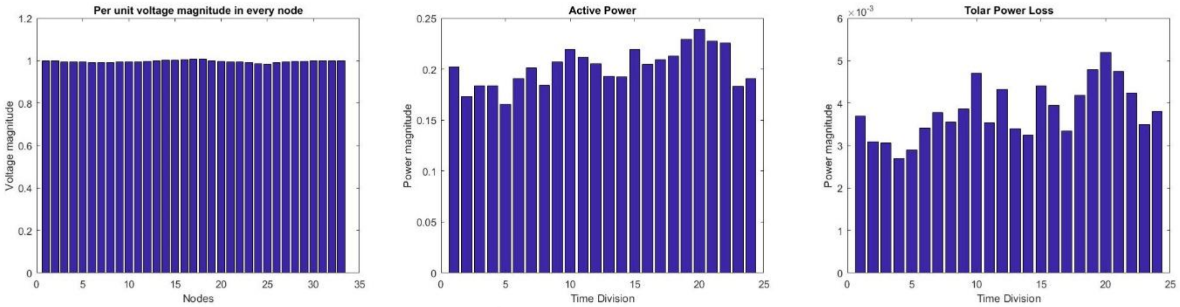


Figure 2: Network Configuration with 2 DGs of 33 bus radial

V.2 Impact on Voltage

The proposed method does not only give the lowest power losses, but also improves the overall voltage profile of thenetwork reconfiguration. Figure 3 illustrated the results gives approx flat voltage profile achieved after reconfiguration.



(a) Voltage Profile (b) Active Power Loss (c) Total Power Loss

Figure 3: The Result for two DG installation

Meanwhile, Figure 3 depicted the results with reconfiguration and DG on voltage profile improvement achieved by theproposed algorithm. In this case, there are improvements on the voltage profile at every bus. While, thevoltage improvement obviously raised to nearby 0.983612517p.u after reconfiguration.The PSO shows a great difference after reconfiguration with DG. Since the PSO gives the fastest solutioncompared to others and its performance is better than traditional methods, it can be concluded that PSO is a superiormethod in reconfiguration with DG process.

VI. Conclusion

PSO technique has been developed in this paper with presence of distributed generators for reconfiguration of thedistribution system. The main objective of this method is to reduce the real power losses and determine the optimum value of DG size simultaneously on the distribution network reconfiguration. A 33-busdistribution system with two distributed generation is used to demonstrate the effectiveness of the proposedtechnique. In this paper, three cases are considered as explained in section IV. The results of the proposed algorithmwhich give the minimum power loss while keeping bus voltage magnitudes within the acceptable limits. Based onthese reasons, it is strongly expected that PSO is capable of solving large-scale problems arose in networkreconfiguration as compared to the existing methods.

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