THE COMBINATION OF HEURISTIC AND META-HEURISTIC ALGORITHM FOR DG SIZING AND SITTING CONCURRENT WITH OPTIMIZING NETWORK CONFIGURATION

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ABSTRACT

A variety of methods have been proposed for addressing optimal location of Dispersed Generations (DG) in distribution networks, usually with the aim of voltage profile enhancement or MV lines' loss reduction. Along with that, an important item which deserves more attention is the reconfiguration of a network after any major change in its structure, including capacitor installation, DG placement, etc. It's obvious that both DG placement and network reconfiguration are interdependent and influence each other directly. Thus, both of these optimizations must be tuned together simultaneously. To aim this end and eschew to aggravate the intricacy of the problem, this paper proposes to combine the robust heuristic reconfiguration algorithm called UVDA with the well known Particle Swarm Optimization (PSO) algorithm. The combinations of these two heuristic and meta-heuristic methods allay the complexity of the problem and lead to more accurate and remarkable results. The simulation results of the proposed method on a 33-node distribution network have been shown to demonstrate its ability.

INTRODUCTION

Currently, a topic that is being frequently discussed is how the electric power distribution systems will be in the future. In this sense, the term Smart Grid was defined to describe how this new network should behave, that is in a smart or intelligent way. Dispersed Generations (DG), as predicted, will play an important role in these networks. Therefore determining the strategic place and size of DGs are highly important in a smart network with the ability to carry out maneuvers in an automated manner (self-reconfiguration) and high reliability, all with a low operation costs. [1].

Many literatures have contributed techniques for optimal sizing and placement of distributed generations (DG) but the majority of them lack optimizing network configuration. Network reconfiguration is one of the most cost efficient and feasible tools for reaching optimal operating condition. It is simply the process of changing the topological structure of distribution feeders by altering the open/closed status of the switches to reach some specific objectives and satisfy operating conditions. These switching operations are performed in a way that the radial configuration of network is maintained and all of the loads are properly energized [2-7].

The earliest methods for network reconfiguration were based on heuristics. Merlyn and Back presented the earliest work on network reconfiguration for loss reduction. They developed a heuristic algorithm that starts from a meshed network obtained closing all switches. The switches are then opened successively to restore radial configuration using the least current as optimality criterion sequential opening [3]. This search technique does not necessarily guarantee global optimization. Shirmohammadi and Hong [4], followed the method presented in [3]. They modeled the weakly meshed networks accurately by using a compensation based power flow technique. Civanlar et al. [5] presented a simple heuristic method to reduce network losses. They formulated a simple algebraic expression to estimate the active loss reduction due to the load transfer between a pair of feeders. The method removes extra load flow runs. Thus, significantly reduces the computational burden. In [7], Baran et al. defined the problem for loss reduction and load balancing as an integer programming problem. They applied Civanlar formulation, with an approximate load flow method using a set of formulas with new Balancing Index.

In our previous paper, we proposed a heuristic constructive reconfiguration method named Uniform Voltage Distribution based constructive Algorithm (UVDA), which is based on the theory of equalizing the ending nodes' voltage to achieve the globally optimal configuration. The method expands the given subnetwork by maximum bus voltage tracing accompanied by a series of branch exchange operation [8]. The main advantages of UVDA reconfiguration method are listed below:

The simplicity of programming, globally optimal convergence (Which is proved through successful implantation on numerous large scale distribution networks and Fast and efficient convergence (compared to other recent approaches).

The major part that must be noticed in the planning of DG placement and sizing is the predominant role of network configuration. In most of the literatures network configuration is kept intact and DG placement and sizing is carried out for the given network.

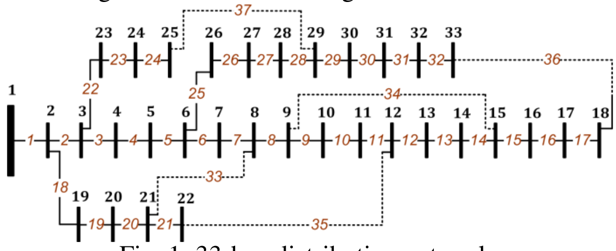

Fig. 1: 33-bus distribution network

In [9], Srinivasa Rao et al used the Meta heuristic Harmony Search Algorithm (HSA) to simultaneously reconfigure and identify the optimal location of DG units in a distribution network. In their approach, the sensitivity analysis is used to determine the optimal place of DG units and, the size and configuration of the network are optimized by the use of HSA. But the method is highly time consuming and is not applicable to real distribution network when either the size of the network or the number of DG units increases. Because the reconfiguration itself is an elaborate and complex process which solely uses a great deal of computational efforts which makes it impractical to compound its intricate nature with extra complexity of capacitor placement and sizing and solving all of these merely with an artificial intelligent algorithm.
To allay the complexity of the problem, this paper proposes the application of artificial intelligence algorithm concurrent with the heuristic reconfiguration algorithm UVDA. The combination of these two techniques fulfills the drawbacks of each method and creates a robust tool for planning the best operational scheme to get the maximum benefits of DG unit installation.

METHODOLOGY

In this section the proposed combined method will be explained. UVDA reconfiguration method, as mentioned in the previously, is used for network reconfiguration and PSO is used for setting of DG units' size and place. Both of which are introduced in this section.

A brief Review of UVDA

A brief explanation of the way UVDA works will be presented in this section. To this end, the well studied 33-bus, 12.66-kV distribution network [7], is chosen to be reconfigured by UVDA. The overall structure of this system with its conventional configuration is depicted in Fig. 1. As shown in this figure, the network consists of five tie lines and 32 sectionalizing switches. The normally open switches are 33 to 37, and the normally closed switches are 1 to 32. The line and load data of the network are reported in [10]. The initial power loss of this network is 202.681 kW. The lowest bus voltage is 0.9131 (p.u).
The overall flowchart of UVDA reconfiguration algorithm is shown in Fig. 2. According to UVDA algorithm [8], there are three types of nodes in a subnetwork, source or root nodes, main nodes and candidate nodes. The primary main nodes are the nodes directly connected to root nodes and the candidate nodes are the nodes directly connected to main nodes. The reconfiguration process of UVDA is illustrated in Fig. 3. The node/load increment process is also shown at each step as UVDA progresses. The very first and primary subnetwork only consists of four nodes including a source/root node, (node number 1), a main node, (node number 2) and two candidate nodes (nodes number 3 and 19). The fast sweep backward- forward (SBF) load flow is performed for this subnetwork at step 1.

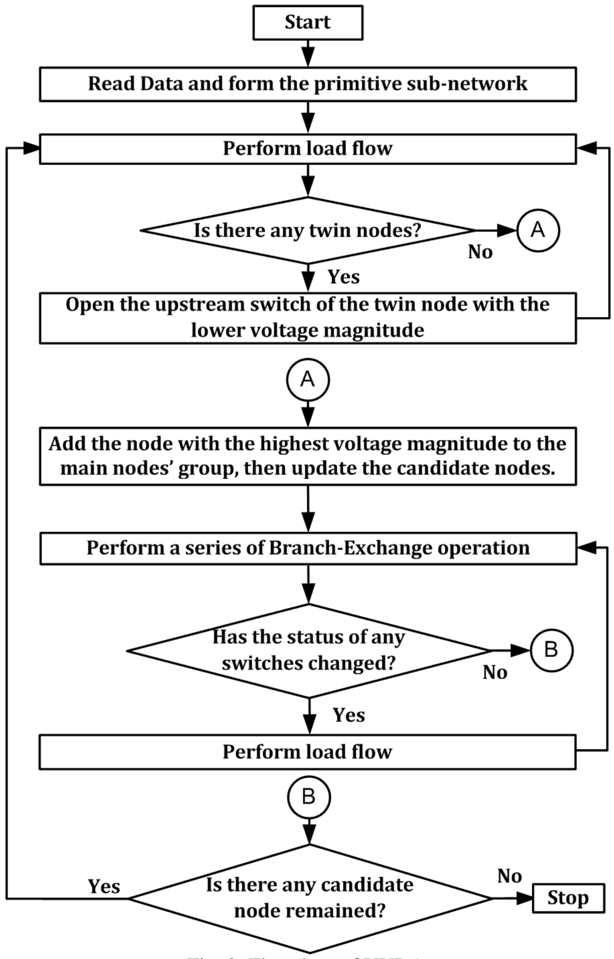

Fig. 2: Flowchart of UVDA

The results indicate that node number 3 has a higher voltage than other candidate node. Hence, it is added to the main nodes group and its directly connected downstream nodes, (nodes number 4 and 23) are added to the candidate nodes group. At each step of UVDA, the load flow program is performed for the expanding subnetwork and the same trend for selecting nodes is followed until the first twin nodes emerge.
The twin nodes are duplication of a candidate node which can be supplied by two different upstream paths. This node is in fact the last energized node of the group of nodes placed along a loop. The duplication of this node prevents loop formation. This means that the subnetwork's configuration is always kept radial throughout the UVDA performance. Thus, the fast radial SBF load flow can be applied to the subnetwork and the overall speed of UVDA can be accelerated. Clearly, one of the twin nodes is surplus and must be eliminated. This surplus node selection is based on twin nodes' supplied voltage at the end of each path. The one path, leading to a higher voltage twin node is maintained intact but the very first upstream branch of the other twin node is opened and the node is eliminated. This is the case shown at step 16 where the twin node is node number 8 and the opened upstream branch is branch number 7. Hereafter, the branch exchange operation will be performed at each step of

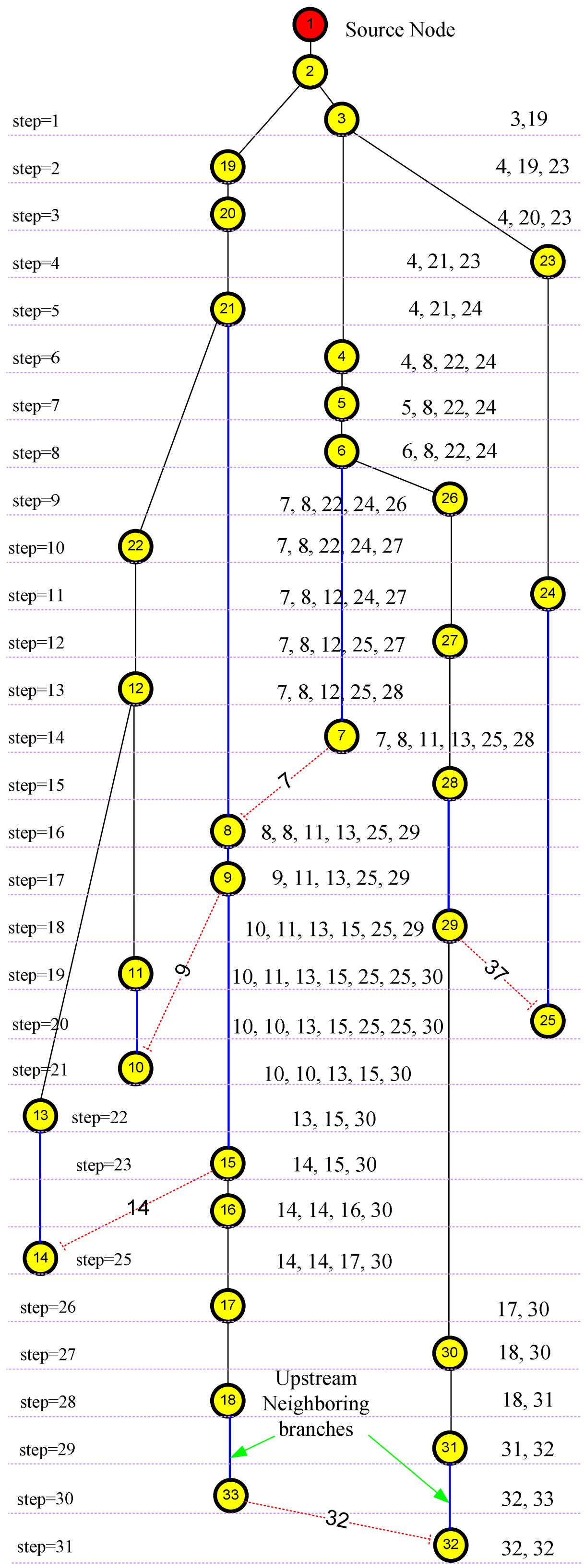

Fig. 3: Illustration of UVDA reconfiguration method on 33-Bus distribution network

load increment to ensure that, the optimality of the subnetwork is strictly followed.

Branch exchange procedure constitutes simply in making exchanges among each of the open switches and their corresponding pair of neighbors. For each switch, two exchange operations are performed involving the pair of neighbors. First, the open switch is closed and the corresponding adjacent switches are opened, one at a time, to explore further optimization [25]. This trend as shown in Fig. 3 continues until the whole network is optimally configured.

It is noteworthy to mention that the high speed and accurate results of UVDA reconfiguration method are highly important factors to its implication for the goal of this paper. Since the reconfiguration methods with poor and time consuming results would drastically aggravate the outcomes of the suggested compound method.

A breif Review of PSO

In order to optimally determine the location and the size of DG units, the well-known PSO artificial algorithm has been implemented. PSO is an optimization technique formulated by Kennedy and Eberhart inspired by the natural behavior of a population of birds or insects [11]. It has been applied successfully to a wide variety of search and optimization problems. In PSO algorithm, each particle keeps track of its own position and velocity in the problem space.

Let the position and the velocity of the ith particle of M population's individuals in the n dimensional search space be represented as $P_i = [p_{i,1}, p_{i,2}, \dots, p_{i,n}]$ and, $V_i = [v_{i,1}, v_{i,2}, \dots, v_{i,n}]$ respectively. Similarly, according to a specific fitness function, the best solution of each particle (local best) and the best solution of the group (global best) are denoted as $P_i^l = [p_{i,1}^l, p_{i,2}^l, \dots, p_{i,n}^l]$ and $P^g = [p_1^g, p_2^g, \dots, p_n^g]$ respectively. The velocity and position are updated at each iteration by the following equations:

$$\mathrm{V}_\mathrm{i}^{\mathrm{it}+1} = \mathrm{w}.\mathrm{V}_\mathrm{i}^{\mathrm{it}} + \mathrm{c}_1.\mathrm{r}_1.\left(P_i^l - P_i^{it}\right) + \cdots$$
$$\mathrm{c}_2.\mathrm{r}_2.\left(P^g - P_i^{it}\right) \quad (1)$$

$$\mathrm{P}_\mathrm{i}^{\mathrm{it}+1} = \mathrm{P}_\mathrm{i}^{\mathrm{it}} + \mathrm{V}_\mathrm{i}^{\mathrm{it}+1} \quad (2)$$

Where V_i^{it+1} is the velocity of ith particle at $(it+1)th$ iteration; r_1 and r_2 are the random numbers selected between 0 and 1, c_1 and c_2 are positive constants having values between $[1,4]$ and it is the index of iteration number. ω is a linearly decreasing inertia weight which increases as a function of iteration index.

$$w = w_{max} - \frac{w_{max} - w_{min}}{it_{max}} \times it \quad (3)$$

Where w_{max} and w_{min} are the initial and final values of w and it are the maximum and current values of iteration respectively. According to (2) each particle's velocity is updated and by (3) the position of the particle is modified.

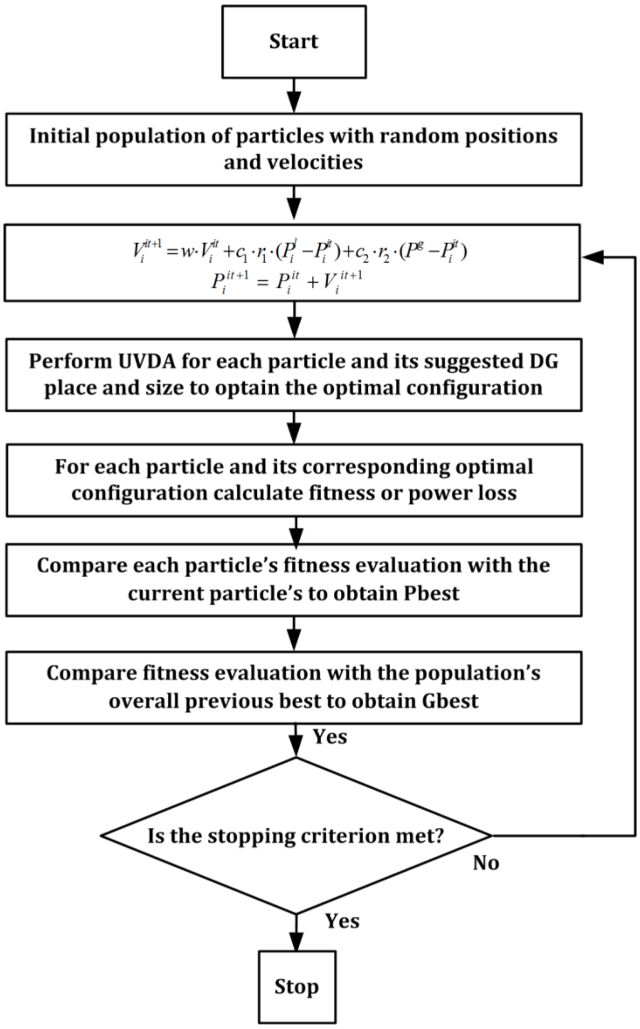

Fig. 4: Flowchart of the proposed method

In this paper, the total power loss of MV lines is selected as the objective function of PSO. The flowchart of the proposed combined algorithm is shown in Fig. 4. As depicted, for each given particle representing the places and sizes of the DG units, one reconfiguration is performed by UVDA and the resultant network power loss is calculated. As it is transparent, the reconfiguration of the network is entirely independent and does not aggravate the performance of PSO.

SIMULATION RESULTS

The proposed method for optimal sizing and placement of DG has been implemented in the MATLAB. The test results for a 33-bus distribution networks are presented and discussed. R. Srinivasa Rao et al. have considered configuration optimization concurrent with DG sitting and sizing [9]. Therefore, their results are used for comparison. The results of load flow and reconfiguration of the network are the same for both of Ref. [9] and the proposed method. In the third scenario, only DG installation is considered and the configuration of the network is not optimized. In this scenario, the capabilities of the three methods in sitting and sizing

Table 1: the results proposed method for different scenarios

senario		Reference [3]	Proposed method
Base case	switches Opened	33,34,35,36,37	
	Power Loss [kW]	202.685	
	Minimum Voltage	0.9131	
Only reconfiguration	switches Opened	7,9,14,32,37	7,9,14,32,37
	Power Loss [kW]	139.55	139.55
	% Loss reduction	31.15%	31.15%
	Minimum Voltage	0.9378	0.9378
Only DG Instalation	switches Opened	33,34,35,36,37	33,34,35,36,37
	Size Of DG in MW &MVar (Bus Number)	0.1070 (18)	0.875 (11)
		0.5724 (17)	0.925 (29)
		1.0462 (33)	0.931 (24)
	Power Loss [kW]	96.76	74.213
	% Loss reduction	52.26%	63.39%
	Minimum Voltage	0.967	0.962
DG installation after reconfiguration	switches Opened	7,9,14,32,37	7,9,14,32,37
	Size Of DG in MW &MVar (Bus Number)	0.2686 (32)	1.125 (30)
		0.1611 (31)	0.592 (15)
		0.6612 (30)	0.526 (12)
	Power Loss [kW]	97.13	66.602
	% Loss reduction	52.07%	67.14%
	Minimum Voltage	0.9479	0.9758
Reconfiguration with simultaneous DG Installation	switches Opened	7,10,14,28,32	7,10,13,27,32
	Size Of DG in MW &MVar (Bus Number)	0.2686 (32)	1.596 (29)
		0.1611 (31)	0.631 (15)
		0.6612 (30)	0.576 (21)
	Power Loss [kW]	73.05	57.185
	% Loss reduction	63.95%	71.79%
	Minimum Voltage	0.97	0.9757

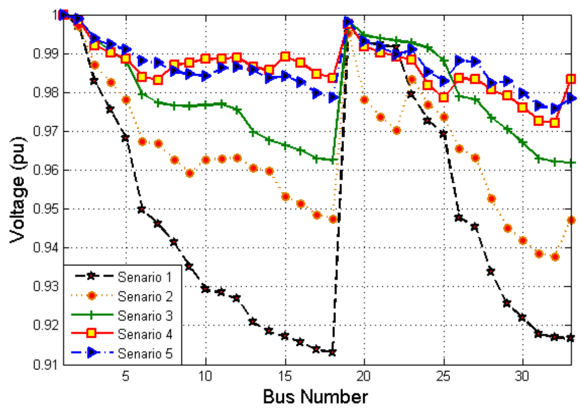

Fig. 5: Voltage profile of 33-bus network for five scenarios

DG units in distribution network are examined. According to the results of this scenario, the performance of the proposed method is noticeably superior to that of reference [9]. For the other scenarios the same conclusion can be made. As shown, the best scenario is obtained when the network configuration is optimized together with the optimization of DG's size and place. In this scenario loss reduction reaches its utmost level 71.79%.

Fig. 5 shows the voltage profile for all the scenarios. As shown, the best voltage profile is achieved when both DG placement and network reconfiguration are considered. In this case, the voltage profile is close to a flat voltage profile which demonstrates a noticeable improvement in comparison to all other scenarios.

CONCLUSION

Network configuration has a great effect on optimal size and location of DG units. On the other hand, DG installation in a network can change its optimal configuration. In order to optimize both of them concurrently and avoid more complication, the combination of heuristic and meta-heuristic algorithm is proposed in this paper. The combination of UVDA and PSO produced an effective tool for the optimum design of network embedding DG units. The results obtained from the implementation of the proposed method on the well studied 33 Bus distribution network confirmed the robustness of the contributed technique. It was shown that the furthest loss reduction of network coincides when both optimization of network configuration and DG place and size are taken into account.

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