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Research paper

Reconfiguration of distribution system and optimal dg placement DG to enhance voltage profile and reduce losses

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Abstract

System reconfiguration which is compelled non linear enhancement issue has been tackled for loss minimization, load balancing, and so on. Another factor of equivalent significance is of DG plays a critical responsibility in the management of distribution system. It's important to optimize its size and location in order extract maximum benefits of its placement. There are number reasons for optimizing the location and sizing, chief among them being reduce power loss and enhancement of voltage profile. Here a hybrid algorithm is proposed for reconfiguration and DG siting is employed to enhance the benefits of DG placement. Non Sorted Genetic Algorithm (NSGA) is employed to reconfigure the distribution system prior to the placement of DG. Once the system is reconfigured, Particle Swarm Optimization (PSO) is employed to recognize the ideal size and placement of DG. The results exhibit the suitability of this combined algorithm in terms reduced power losses and enhanced voltage profile. Results are compared and analyzed for DG placement with and without reconfiguration for IEEE 69 bus distribution system.

Keywords: *NSGA, sizing, location, DG, PSO, reconfiguration, IEEE 69 bus system, Power loss.*

1. Introduction

Distributed Generation plays an important role in electricity markets and power systems. Installation of DG on distribution feeders can have a considerable collision on power system operation and control [1]. DG can be fitted with different strategies in the power network. For example, reducing power losses, cost reduction peak load, improving voltage profile or system reliability, all depend on the size and placement of the DG [2]. Since determination of ideal area and capacity of DG unit is likewise a composite combinatorial enhancement issue, numerous techniques are proposed around there in the current past [3]. Wang and Nehrir [4] proposed a systematic strategy to decide ideal area to put a DG in the distribution network for loss reduction. Celli et al. [5] introduced a multi-target calculation utilizing GA for siting and estimating the size of DG in the distribution system.

Optimal network reconfiguration is, in fact, the best network configuration among all existing configurations in the network. Since distribution networks are configured in a radial manner, switches that are normally open or closed are strategic points of the network for reconfiguration. In general, reconfiguration to decrease power losses and eliminate overload or voltage profile improvement in the network takes place which with the feeder load change and the proper opening and closing of the switches can perform these actions [6]. Distribution network reconfiguration is an issue of complex multi-target integer collecting optimization. A heuristic algorithm proposed by Merlin and Back [7], to resolve the minimum loss design. In that technique, initially all switches are closed, then the network as meshed network. Civanlar et al. [8] intended a heuristic algorithm to restore radial configuration, the switches are opened progressively. Artificial intelligence methods have additionally been connected to distribution network reconfiguration problems extensively, for instance, genetic algorithms [9], neural networks [10], simulated annealing [11], swarm optimization [12], ant colonies [13].

Kyu-Ho Kim et. al. [14] utilized a hybridized technique, N. Acharya et. al. [15] suggested an explanatory strategy, S. Kamalinia, et-al [16] introduced Multi-Attribute Decision Making ,In [17] Particle Swarm Optimization (PSO) strategy, M. Abbagana et. al. [18] suggested a Differential Evolution method and In [19] a Meta heuristic Harmony Search Algorithm (HSA) is utilized for deciding DG size and area in distribution system.

In this work an objective function is intended for network reconfiguration to increase the load supplied by reducing losses, and it is optimized by utilizing the Non-dominated Sorting Genetic Algorithm-II[20]. After reconfiguration multi idea function is utilized to find the ideal location and capacity of the DG resource. PSO (Particle Swarm Optimization) is utilized for optimizing the multi objective function. Major intention of the function is to recognize the proper siting and estimating the range of DG so as to decrease the power loss and progressing overall system voltage profile. The primary constraints considered for optimization include the power loss, voltage profile and thermal flow limits. The recommended approach is validated using an IEEE 69 bus radial distribution system.

2. Problem statement

The major aim of this formulation is reconfiguration of Distribution Network and to ensure that estimating the ideal position and capacity of DG unit while reflect on several intentions of voltage profile enhancement and reduction in total power loss and.

The feeder will be reconfiguring by maximizing the following objective function.

$$Maximize \sum_{i \in N} w_i \, p_{Li} \qquad (1)$$

Where,
N : Number of Load Points,
w : priority of the load given as a weight,
PLi : The load power.

The target work for reconfiguration is subjected to the accompanying confinements;
(i) The total load should not exceed the total generation.
(ii) The power flow through any distribution line or switch should not greater than the capacity of the switch.

Another objective function for location and sizing of DG, various objectives are combined through weights to form a liner function which represent all the three objectives.

The main constraints considered in this work are;

1. Loss with DG $\leq$ Loss without DG
2. $V_{bus\ min} \leq V_{bus} \leq V_{bus\ max}$
3. Line limits: $S_L \leq S_{max\ L}$, $\forall = \{1, 2, 3\ldots L\}$,

Where SL is the thermal limit of each line and L is total lines in the system.

The multi objective function [21] is expressed as

$$\text{Max(F)}=W1\{Max[0,1/n\sum_{i=1}^{n}(Voltage\ \%_{\ i\ with\ DG} - Voltage\ \%_{\ i\ without\ DG})]\} + W2\{Max[0,1/n\sum_{i=1}^{n}(P_{\ j\ with\ DG} - P_{\ j\ without\ DG})]\} + W3\{Max[0,1/n\sum_{i=1}^{n}(Q_{\ j\ with\ DG} - Q_{\ j\ without\ DG})]\} \qquad (2)$$

$Voltage\ \%_{\ i\ With\ DG}$ and $Voltage\ \%_{\ i\ Without\ DG}$: Percent of voltage in ith bus with and without DG,
$P_{\ j\ With\ DG}$ and $P_{\ j\ Without\ DG}$: Active Power Losses in jth branch with and without DG,
$Q_{\ j\ With\ DG}$ and $Q_{\ j\ Without\ DG}$: Reactive Power Losses in jth branch with and without DG,
n and m is Number of Buses and Branches
W1, W2 and W3 are weights are assumed to be equal and Where W1+W2+W3=1.

Repeated information should not be reported in the text of an article. A calculation section must include experimental data, facts and practical development from a theoretical perspective.

3. Non-dominated sorting genetic algorithm-II (NSGA-II)

NSGA-II is recommended to be employed to automatically reconfigure the feeder. NSGA-II is basically a updated version of usual GA. NSGA also uses selection, mutation and crossover operators like conventional GA to produce mating pool and offspring population. NSGA-II algorithm flow chart for proposed reconfiguration is exposed in Fig. 1.

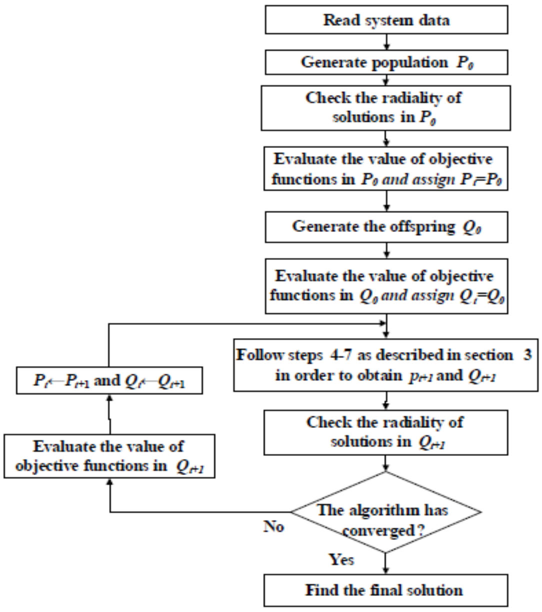

Fig. 1: NSGA-II algorithm flow chart for proposed reconfiguration

4. Particle swarm optimization (PSO)

PSO is most efficient algorithms in the area of swarm intelligence. Eberhart et al. was first introduces the PSO algorithm in the year 1995 [22]. PSO is moreover a populace supported approach and it doesn't employ operators like mutation, cross over and selection. It is a meta-heuristic algorithm and has very few hypotheses as regards the problem being optimized and is able to look for very huge spaces of candidate solutions. In PSO, solution is assumed as a bird in the investigating space and is known as "particle". PSO initially configures a group of arbitrary particles and then through repeated searching finds the optimum solution. In every iteration the best position identified with a particle is called p_{best} ; similarly, the best position identified with the entire swarm is known as g_{best}. For every particle the velocity and its position are modernized by utilizing the following equations

$$v_i^{k+1} = w \times v_i^k + c_1 \times r_1 (p_{best\,i} - x_i^k) + c_2 \times r_2 (g_{best\,i} - x_i^k) \qquad (3)$$

$$x_i^{k+1} = x_i^k + \chi \times v_i^{k+1} \qquad (4)$$

5. Test system description

For case study, a radial distribution system considered with line voltage 12.66 kV, 69 buses, 5 tie – lines (looping branches) and 7 laterals[22].The total P_{Loss} (real power loss) and Q_{Loss} (reactive power loss) are 224.9457 kW and 102.1397 kVAr. The lowest voltage of this system is 0.9092 p.u. at bus 65. The figure (2) shows the IEEE 69 bus test system.

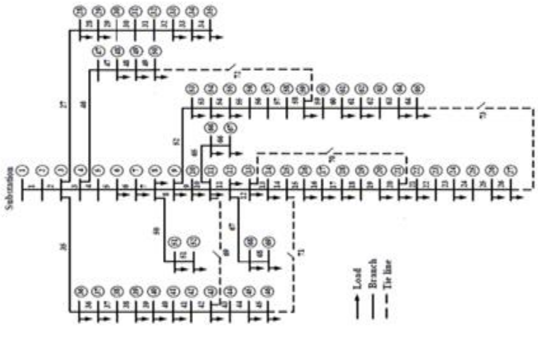

Fig. 2: Radial distribution system (IEEE 69 bus)

6. Results and discussions

The recommended approach is veiled by utilizing Matlab R2012a Version and MatPower version 5 [23] is utilized to execute the optimal power flow solver utilizing Gauss-Seidel power flow. The iteration settings for PSO incorporate most extreme 100 quantities of iterations, with acceleration constant of 2.0 and 2.8 and greatest and least inertia weights at 1.0 and 0.2 separately. The greatest and least velocity of particles is fixed at 0.9 and 0.4 respectively. The results are analyzed and discussed for 69 bus distribution system.

In order to validate and understand the performance of the recommended approach three test cases are considered as mentioned below.

Case 1: Maximum size of DG in percentage of summation of total load is fixed at 10 %

Case 2: Maximum size of DG in percentage of summation of total load is fixed at 20 %

Case 3: Maximum size of DG in percentage of summation of total load is fixed at 30 %

Case 1: Maximum size of DG is 10% of load

In case of 69 bus system the initial tie switches before reconfiguration are 69, 70, 71, 72 and 73. For this configuration before the site of DG the P_L of the network is calculated at 224.98 KW while the Q_L is calculated at 169.75 KW. The DG placement using PSO optimize the location for this case at bus 64 placing a DG of size 380.189 KW.

Table 1: Result of Optimization of DG Placement and Sizing Including Reconfiguration for 69 Bus System for Case- I

Case-1	**Tie Switches**	**DG Size (KW)**	**DG Location Bus No.**	**P_L (KW)**	**Q_L (KVAR)**	**Minimum Voltage Profile At Bus No.**	**Minimum Voltage (PU)**
Before DG Placement	69, 70, 71,72,73			224.98	102.156	65	0.909187
After DG Placement Prior to Reconfiguration	69, 70, 71,72,73	380.189	64	169.75	78.6233	65	0.911672
After DG Placement Post Reconfiguration	14, 57, 61, 69, 70	380.189	61	73.73	65.58	61	0.952768

The placement of DG at this bus reduces the real power loss (P_L) to 169.75 KW and the reactive power loss (Q_L) to 78.6233 KW. The results are shown in Table 1. There is an improvement in the voltage profile too. The minimum voltage profile which was observed at bus 65 improved to 0.911672 from 0.909187. The reconfiguration altered the tie switches, the new configuration have tie switches as 14, 57, 61, 69 and 70. The system was again optimized for location and size post reconfiguration, now the real power loss (P_L) reduced to 73.73 KW and the reactive power losses (Q_L) reduced to 65.58. A huge upgrading in the voltage profile is also detected, after reconfiguration the DG of size 380.189 now placed at bus number 61 resulted in an enhanced minimum voltage of 0.952768 monitored at bus 61. The plot power loss for different scenario is specified in figure (3).

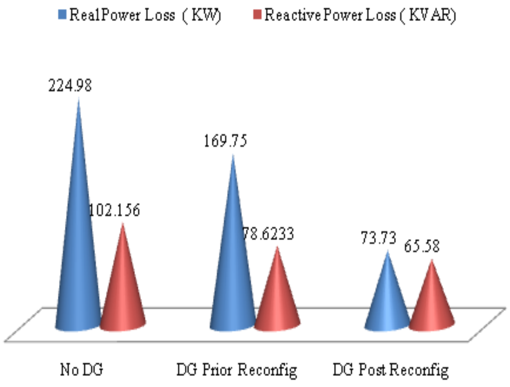

Fig. 3: Comparative plot of Real Power and reactive power losses for different scenarios in case 1

Table 2: Result of Optimization of DG Placement and Sizing Including Reconfiguration for 69 Bus System for Case-II

Case-1	**Tie Switches**	**DG Size (KW)**	**DG Location Bus No.**	**P_L (KW)**	**Q_L (KVAR)**	**Minimum Voltage Profile At Bus No.**	**Minimum Voltage (PU)**
Before DG Placement	69, 70, 71,72,73			224.98	102.156	65	0.909187
After DG Placement Prior to Reconfiguration	69, 70, 71,72,73	760.378	61	130.145	61.6737	65	0.914106
After DG Placement Post Reconfiguration	13, 20, S56, 63, 69	760.378	61	66.4957	51.5306	62	0.95168

Case 2: Maximum size of DG is 20% of load

The results of the optimization for this case are summarized with the help of table 2. For this case a DG of size 760.378 is placed at bus 61, bringing down the real power losses (P_L) to 130.14 KW and the reactive power losses (Q_L) to 66.50 KVAR. An increase in voltage profile is also observed, with an increase from 0.909187 to 0.914106. Post reconfiguration the tie switches are 13, 20, 56, 63 and 69. For this reconfigured network the location and capacity of the DG remained the same, but a greater reduction in losses can be observed. The real power loss fell to 66.4957 signaling more than 50 % reduction when compared to placement before reconfiguration. The reactive power losses also fell to 51.5306. There is huge improvement in voltage profile too, with a minimum voltage of 0.95168 monitored at bus number 62. The plot of power loss for different scenario is given in figure (4).

Case 3: Maximum size of DG is 30% of load

The results of the optimization for this case are summarized with the help of table 3. For this case a DG of size 1140.57 is placed at bus 61, bringing down the real power losses (P_L) to 102.953 KW and the reactive power losses(Q_L) to 57.6975 KVAR. An increase in voltage profile is observed from 0.909197 to 0.951687. Post reconfiguration the tie switches are 13, 20, 56, 63 and 71. For this reconfigured network the location and capacity of the DG remained the same, but a greater reduction in losses can be observed.

The real power loss fell to 57.6795 signaling more than 40% reduction when compared to placement before reconfiguration.

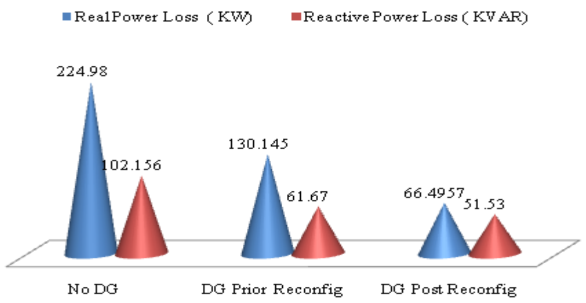

Fig. 4: Radial comparative plot of real and power and reactive power losses for different scenarios in case 2

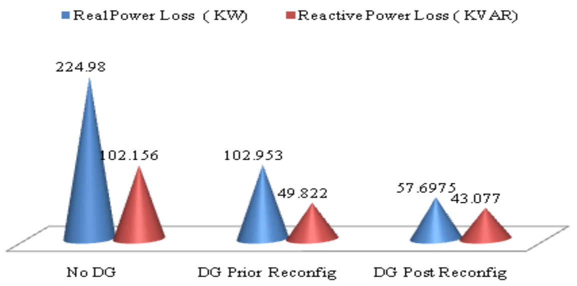

Fig. 5: Radial Comparative plot of real and power and reactive power losses for different scenarios in case 3

Table 3: Result of Optimization of DG Placement and Sizing Including Reconfiguration for 69 Bus System for Case-III

Case-1	**Tie Switches**	**DG Size (KW)**	**DG Location Bus No.**	**P_L (KW)**	**Q_L (KVAR)**	**Minimum Voltage Profile At Bus No.**	**Minimum Voltage (PU)**
Before DG Placement	69,70,71, 72,73			224.98	102.156	65	0.909187
After DG Placement Prior to Reconfiguration	69,70,71, 72,73	1140.57	61	102.953	49.8222	65	0.916493
After DG Placement Post Reconfiguration	13,20,56,63,71	1140.57	61	57.6975	43.0771	62	0.951687

The reactive power losses also fell to 43.0771.There is huge improvement in voltage profile, with a minimum voltage of 0.95168 detected at bus number 62. The plot of power loss for different scenario is specified in figure (5).

The following figure (6) sums up the location and size of DG for different scenarios placed after reconfiguration using the proposed approach for 69 bus system.

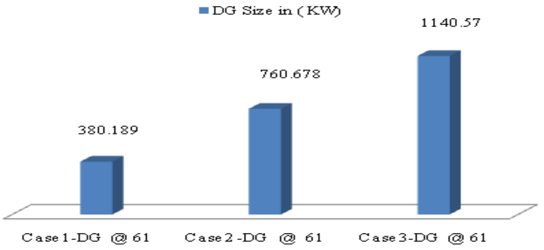

Fig. 6: Optimum DG size and location for different cases placed after reconfiguration

The following table (4) summarizes the net impact of reconfiguration on bringing down loses when compared to simple DG placement without reconfiguration. The comparison is made in regard to real power losses to give an indication about the effect of reconfiguration. From the table 9, it can be observed that, reconfiguration brings about a quantum reduction in losses when compared to DG placement without reconfiguration. It's important to observe that this reduction in losses is brought about without any increase in the DG size

Table 4: Reduction in Real Power Loss for DG Placement after Reconfiguration

Test System	**Case**	**P_L After DG Placement Without Reconfiguration**	**P_L After DG Placement After Reconfiguration**	**% Reduction In Losses**
IEEE 69 Bus Distribution System	Case 1	169.75	73.73	56.57
	Case 2	130.15	66.50	48.91
	Case 3	102.95	57.70	43.95

The placement of DG in a reconfigured network also brings about increasing voltage profiles of different buses. The plot of voltage profiles for different cases before and after reconfiguration and with and without the placement of DG is illustrated in the Figure (7).

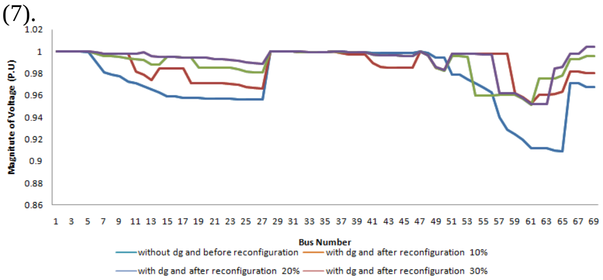

Fig. 7: Bus voltage profiles before and after reconfiguration with and without DG placement

7. Conclusion

In this paper a hybrid algorithm for solving optimal distribution network reconfiguration and optimal DG placement with the objective of improving voltage profile and reducing power loss was successfully presented. The first algorithm for solving reconfiguration is a NSGA-II algorithm. The second algorithm for solving optimal DG placement is to use a PSO Algorithm which estimates optimal places for installing DG and their value. The results are compared and analyzed for DG placement with and without reconfiguration for IEEE 69 bus distribution system. From test system it can observe that there is appreciable reduction in losses when the DG is placed after reconfiguration. It can also be inferred that reconfiguration also has a positive impact on the voltage profile of the system. The proposed approach has been designed and presented in the form of a Graphical User Interface (GUI) enabling ease of use for the user.

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